

A Model for the Nation: Promoting Education and Innovation in Vermont's Electricity Sector

Summary of Activities Completed Through the Department of Energy Power Systems Fellowship Program Under Inter-Entity Work Order Number M610000767

Laurie Burnham, Robert Q. Hwang and Juan J. Torres

Prepared by
Sandia National Laboratories



A Model for the Nation: Promoting Education and Innovation in Vermont's Electricity Sector

Summary of Activities Completed Through the Department of Energy Power Systems Fellowship Program Under Inter-Entity Work Order Number M610000767

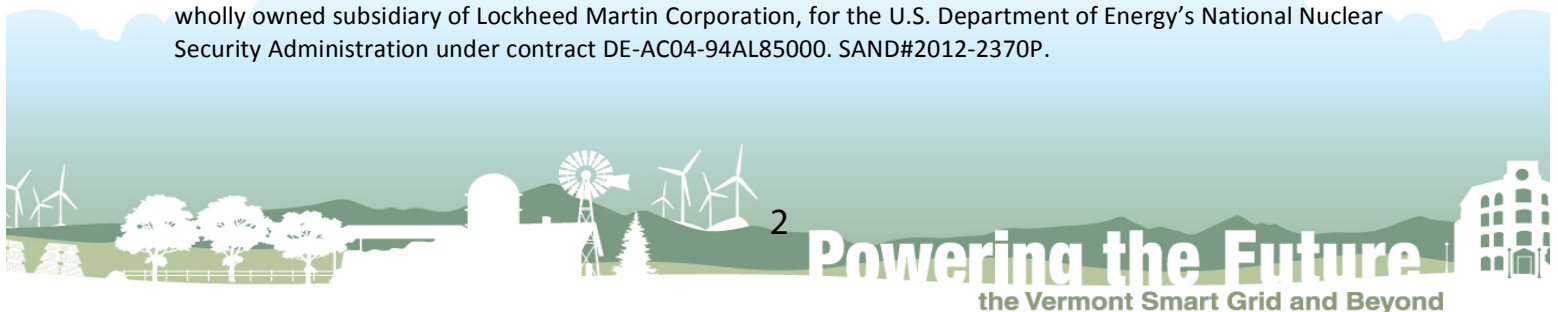
Prepared by the Energy, Climate, and Infrastructure Security
Strategic Management Unit Office

Sandia National Laboratories
P.O. Box 5800
Albuquerque, New Mexico 87185

ABSTRACT

In FY 2011, with support from the U.S. Department of Energy Power Systems Fellowship Program, Sandia National Laboratories partnered with a diversity of Vermont organizations, including utilities, energy technology companies, and academic institutions, to develop a set of educational, training, and research activities that would support and further smart grid deployment in Vermont. These activities included a public seminar series at the University of Vermont called "Powering the Future;" a multidisciplinary, multisectorial statewide conference; a set of technology short courses for utility workers and other stakeholders; a public outreach display at a Vermont science center; and collaborative research focused on four key areas: smart grid, complex systems, policy, and human behavior. Overall, this partnership reflected the synergies between Sandia, which has deep technical expertise in energy delivery systems, and the state of Vermont, which has a strong commitment to sustainability, a supportive regulatory framework, and an unprecedented history of utility collaboration with respect to smart grid deployment. By working together in this way, it is hoped that Sandia and Vermont can drive fundamental change in the electric sector, change that translates beyond Vermont to further energy transformation in the rest of the nation.

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. SAND#2012-2370P.

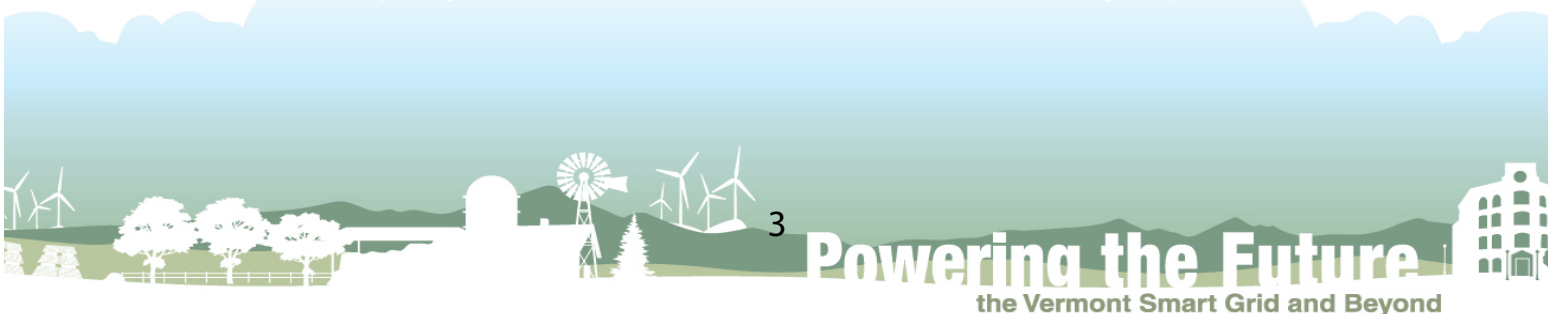


ACKNOWLEDGMENTS

The authors gratefully acknowledge financial support from the U.S. Department of Energy Power Systems Fellowship Program and the backing of Gil Bindewald, program manager in the Office of Electricity Delivery and Energy Reliability (OE), who believes innovative approaches to workforce development in the electric sector are essential to our nation's energy security. We also acknowledge Patricia Hoffman, Assistant Secretary in the Office of Electricity Delivery and Energy Reliability, and Dan Ton, also from OE, who participated in the project's "Powering the Future" conference, inspiring the audience and adding greatly to the event's overall success.

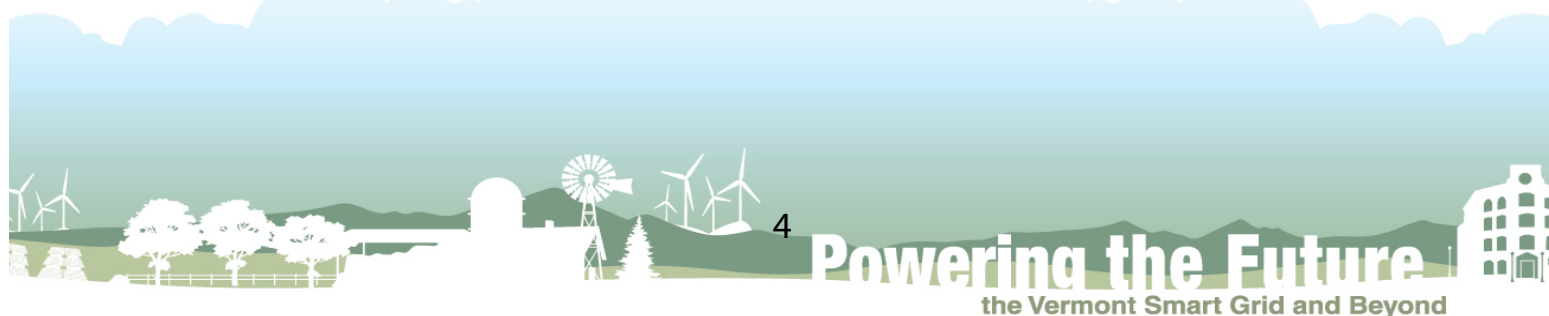
Although many individuals at Sandia and in Vermont contributed to this project in myriad fundamental ways, ranging from providing communications and logistical support to spearheading collaborative research projects, three persons deserve special recognition: John Evans, Special Advisor to the President of the University of Vermont, Mary Powell, President and CEO of Green Mountain Power, and Marjorie Tatro, Director of Energy Technologies and System Solutions at Sandia. As members of the partnership steering committee, each of these individuals worked tirelessly on behalf of the project, deeply believing in its enduring value and willingly providing the vision, guidance, and time to ensure its success.

In addition, we thank U.S. Senator Bernie Sanders and his staff, notably Huck Gutman and Darren Springer for their unshakable belief in the value of a Vermont-Sandia partnership and for being the catalyst that brought the partnership to life; Governor Peter Shumlin of Vermont and his staff for their participation and counsel; the University of Vermont, especially the Office of the Vice President for Research, for its active engagement, intellectual contributions and steadfast support; the Vermont utilities, collectively known as the e-Energy Vermont group, for their ongoing advice and guidance; the Vermont Law School's Institute for Energy and the Environment for its outstanding policy contributions and superb teaching of a short course; Norwich University for its expertise in cybersecurity and ongoing engagement; the Vermont State College System for its commitment to workforce education and willingness to help forward the project's goals; and the ECHO Lake Aquarium and Science Center for partnering on smart grid outreach activities and being consistently interested in the project. Sandia also thanks Vermont's private-sector energy companies, including AllEarth Renewables, Alteris Renewables, Control Technologies, Draker Laboratories, GroSolar, IBM, NRG Systems, Omega Optical, and SBElectronics for their engagement and for their sponsorship of the ECHO smart grid display. And finally we thank Rick Stulen, Vice President of Energy, Climate, and Infrastructure Security at Sandia, for his unwavering commitment to the project and for his deep belief that an enduring partnership between Sandia and Vermont stakeholders can play a significant role in steering our nation to a better energy future.



CONTENTS

Executive Summary	6
Introduction	8
Project Objectives	8
The Sandia-Vermont Partnership	9
Vermont: A Leader of Energy Innovation	10
Sandia National Laboratories: Exceptional Service in the National Interest	11
Organizational Structure	11
Project Activities	12
I. Education and Training	13
Powering the Future Seminar Series	13
Technology Short Courses	14
II. Stakeholder Outreach	16
Utilities Workshop	16
Stakeholder Conference	17
ECHO Science Center	18
e-Energy Vermont Communications Working Group	20
III. Collaborative Research	20
Research Topics:	20
Student and Faculty Exchange	21
Research Projects	22
Conclusion: Making an Impact	22
Appendix 1: UVM-Sandia Strategic Planning Session	24
Appendix 2: e-Energy Vermont Meeting to Explore Collaboration	28
Appendix 3: e-Energy Vermont Meeting Agenda	30
Appendix 4: e-Energy Vermont Meeting Summary	32
Appendix 5: The Vermont Smart Grid Partnership Stakeholder Conference Welcome Letter	37
Appendix 6: The Vermont Smart Grid Partnership Stakeholder Conference Meeting Agenda	38
Appendix 7: The Vermont Smart Grid Partnership Stakeholder Conference Breakout Sessions and Recommendations	40
Appendix 8: Smart Grid Technology Courses	52
Appendix 9: Smart Grid Outreach at the ECHO Lake Aquarium and Science Center in Burlington, Vermont	55
Appendix 10: UVM – Sandia Research Exchanges	58
Appendix 11: Collaborative Research	60



FIGURES

Figure 1. *Organizational Chart for the Sandia-Vermont partnership in FY2011.* 12

Figure 2. *Timeline of the activities that helped develop and define the Sandia-Vermont partnership for energy transformation and innovation.*..... 13

Figure 3. *Technology short courses, aimed at both professionals and students, appealed to a diverse audience.* 15

Figure 4. *Powering the Future conference drew more than 150 participants from multiple sectors.* 18

Figure 5. *University of Vermont students engage ECHO Science Center visitors in a game of "Smart Grid Jeopardy."* 19

Figure 6. *Schedule for University of Vermont researchers visiting Sandia in 2011.* 59

Figure 7. *Student interns from the University of Vermont spent the summer of 2011 at Sandia researching topics related to the smart grid.* 60

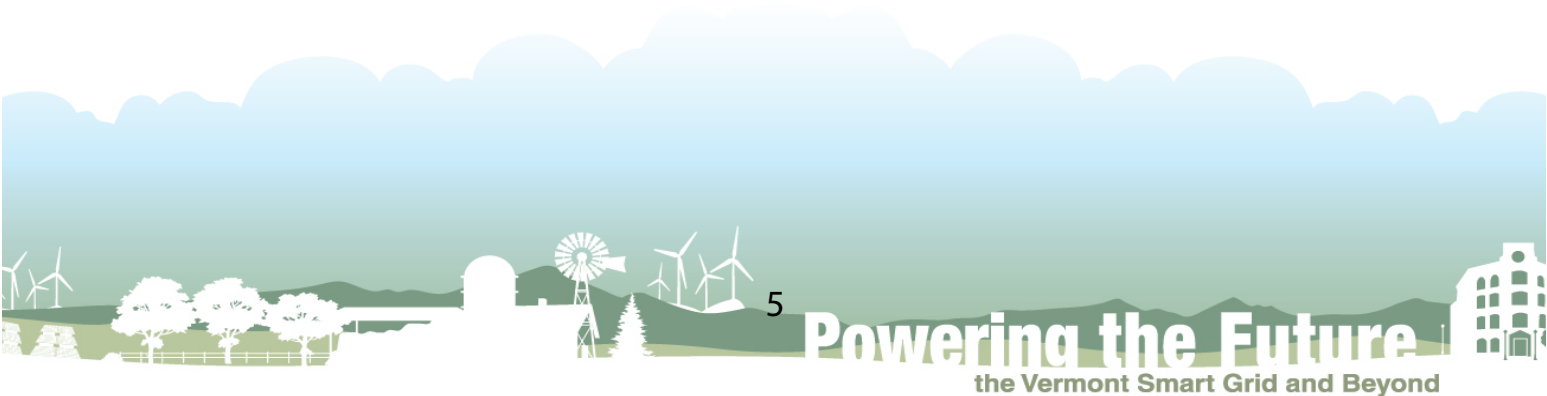
TABLES

Table 1. Collaborative Research Topics Related to the Smart Grid 20

Table 2. Collaborative Research Projects launched by Sandia and UVM in 2011 22

Table 3. Jobs Created and/or Supported by the DOE Power Systems Fellowship Program..... 23

Table 4. A Collaborative Effort: Stakeholders in the Vermont-Sandia Partnership..... 23



A Model for the Nation: Promoting Education and Innovation in Vermont's Electricity Sector

*Summary of Activities Completed Through the Department of Energy Power Systems
Fellowship Program Under Inter-Entity Work Order Number M610000767*

EXECUTIVE SUMMARY

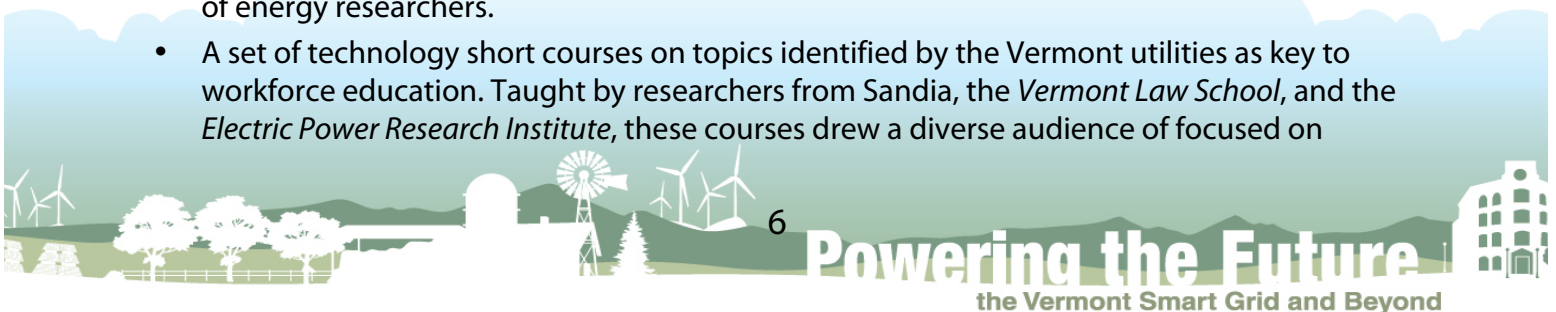
In fiscal year 2011, the U.S. Department of Energy awarded *Sandia National Laboratories* a grant to work in partnership with the *University of Vermont* (UVM) and other stakeholders to promote workforce development and the creation of an interdisciplinary community to foster innovation and technological advancement in the electric power sector.

The funds awarded for this effort helped address the following two needs: (1) a national shortage of trained workers who understand the information technology complexities of the smart grid and other 21st-century grid challenges, including high penetration of renewable energy and infrastructure security (as well as related policy and economic issues) and (2) Vermont's near-term needs for a workforce capable of deploying, overseeing, and maintaining the state's emerging smart grid, which is scheduled to be in place statewide by the end of 2013.

The focal point of this year-long collaborative effort was a set of educational initiatives, including a series of seminars and short courses, which provided training for electric-sector workers, sparked research collaborations with Vermont's academic institutions and engaged a diverse group of private and public stakeholders, promoting interaction among them.

More specifically, these activities included:

- Regular interactions with Vermont's electric utilities and the Vermont Department of Public Service, a group known collectively as *e-Energy Vermont*, to ensure that the activities supported by this grant contributed directly to smart grid deployment efforts in Vermont.
- A series of public seminars in Vermont, presented by Sandia researchers on various topics related to energy innovation. Held at UVM and attended by a broad representation of stakeholders—including students, faculty, the electric utilities, technology companies, and government representatives—the seminars sparked ongoing dialogue and created a platform for future collaboration between Sandia and Vermont.
- A conference to bring stakeholders from across Vermont together to discuss energy innovation in Vermont and to explore opportunities for the state—the first to deploy a statewide smart grid—to become a national leader in smart energy systems. Topics included smart grid technologies, energy security, job opportunities, and partnerships and policies related to the environmental benefits of smart grid. The event also showcased the work of high school students who had conducted energy-related research for the Vermont State Science and Math Fair, acknowledging the role they may play as the next generation of energy researchers.
- A set of technology short courses on topics identified by the Vermont utilities as key to workforce education. Taught by researchers from Sandia, the *Vermont Law School*, and the *Electric Power Research Institute*, these courses drew a diverse audience of focused on



utility workers, government and private sector employees and university students who wanted to better understand smart grid implementation challenges and opportunities.

- Supported faculty research opportunities and student internships at Sandia National Laboratories during the summer of 2011 in the following topic areas: smart grid performance, consumer decision-making, and policy analysis.
- A public outreach effort at Vermont's ECHO Lake Aquarium and Science Center to educate the public about electricity as well as the need for—and the benefits of—the smart grid to Vermont. Targeted at the general public and developed with the help of engineering students at UVM, the project had two primary purposes: to educate consumers about the smart grid and to collect data on visitors' understanding of the electric grid to help inform future research.

The effort also spawned a long-term strategic partnership between Sandia and the State of Vermont that has been wide ranging in its impact, touching on issues that range from the technical to the social and involving multiple Vermont institutions. Amounting to a catalyst for interinstitutional research in topics relevant to the smart grid, the result has been an unprecedented level of engagement among policy experts, social scientists, security and computer experts, computational modelers, engineers, and economists, creating the foundation for a systems-based and holistic approach to energy innovation in Vermont.

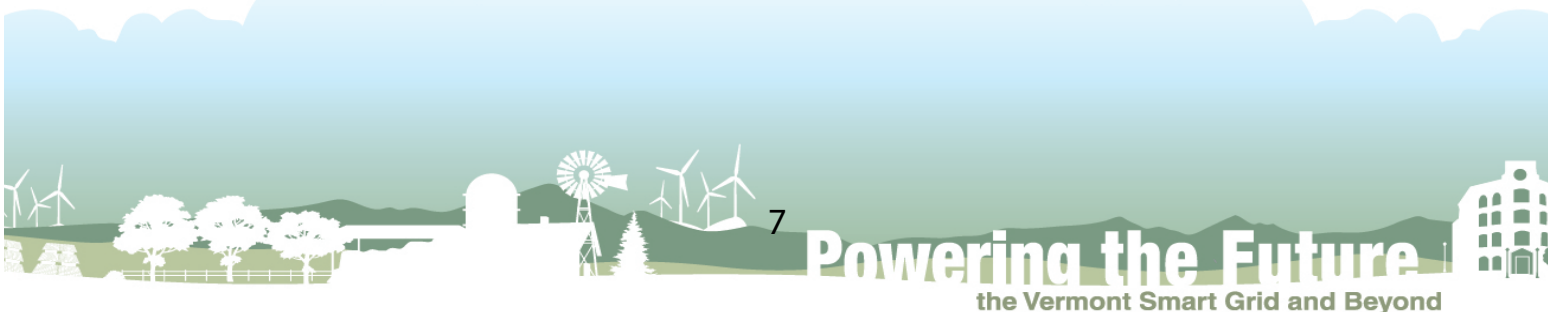
The core partners in this year-long collaboration brought unique but complementary strengths to the project, making it possible to meld Sandia's deep technical expertise in energy delivery systems with Vermont's experience in energy projects, its commitment to sustainability, supportive regulatory framework, and unprecedented history of utility collaboration.

Working more broadly with Vermont's policymakers, utilities, educational institutions, nonprofit organizations, privately owned companies, and citizen groups, Sandia researchers provided—and continue to provide—a high level of technical expertise to help transform the state's electric grid into a more reliable, secure, and affordable "smart grid." As part of this effort, they are helping integrate new renewable and distributed energy sources, working with utilities to secure the grid against cyber attack and conducting research to better understand consumer response to the smart grid.

By collaborating in this way, with a focus on best practices, Vermont is poised to emerge as a model for the U.S. Not only will it be the first state in the nation to deploy a statewide smart grid, but as a result of its partnership with Sandia, Vermont has the potential to create a set of best practices that can be replicated by other states, hastening our nation's trajectory toward a better energy future.

Stakeholders across Vermont—in partnership with Sandia National Laboratories—are working toward a sustainable energy future, creating a model for statewide collaboration that reflects unprecedented trust, communication, and innovation.

communication and innovation
research publications and



A Model for the Nation: Promoting Education and Innovation in Vermont's Electricity Sector

Summary of Activities Completed Through the Department of Energy Power Systems Fellowship Program Under Inter-Entity Work Order Number M610000767

Introduction

As the 21st century unfolds, it is increasingly clear that the United States—and indeed the world—faces unprecedented energy challenges. The electric grid, which is widely viewed as our nation's most critical infrastructure (it is—in today's digital and electronic world—the one on which all other infrastructures depend), has remained essentially unchanged since its rollout at the end of the 19th century. At the same time, the nation's insatiable appetite for electricity continues to grow, adding stress to the grid and increasing our dependence on fossil fuels, much of the latter imported and virtually all of it contributing to greenhouse gas emissions.

This stress has, in turn, led to an increase in electricity outages each year, underscoring the fact that our nation's century-old grid badly needs modernization and an advanced communications overlay befitting the 21st century. Upgrading the grid in this way, and ensuring it continues to operate in a manner that is safe, secure, reliable, and efficient, is not only vital to American competitiveness in a global arena but to securing our nation's energy future and the continued wellbeing of every American citizen.

Although many of the upgrade challenges are technical in nature, others are economic or political; even educational. In fact, according to the U.S. Power and Engineering Collaborative, "Aging trends in the electrical engineering workforce...will make it difficult to meet [the smart grid's] reliability expectations unless action is taken today," a sentiment echoed by U.S. Secretary of Energy, Steven Chu, who said in 2010 that "Building and operating smart grid infrastructure will put tens of thousands of Americans to work [but we need to] ensure that we have the workforce in place to meet this need."

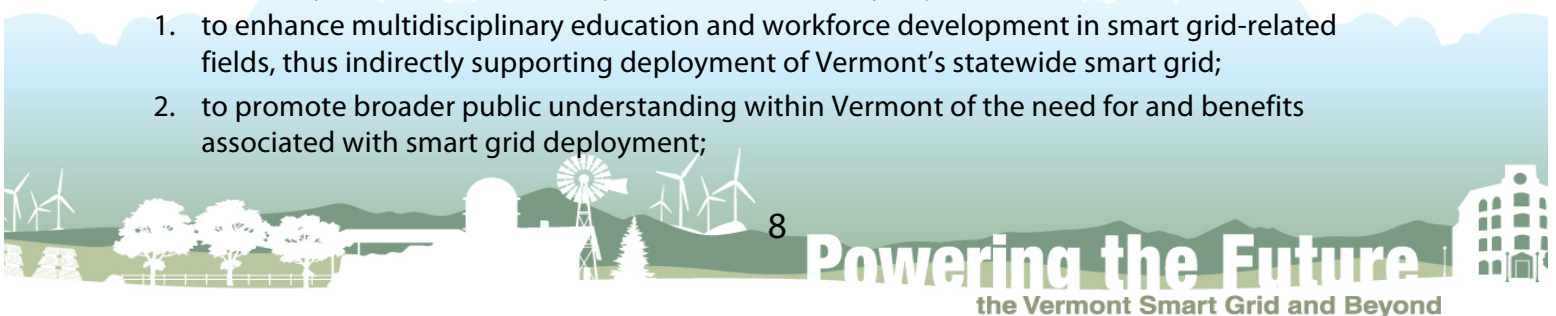
Project Objectives

Recognizing the link between education and successful smart-grid deployment, the U.S. Department of Energy (DOE), through its Power Systems Fellowship Program, provided Sandia National Laboratories with funding to initiate a partnership with the *University of Vermont* (UVM) and other Vermont stakeholders to support various educational and outreach initiatives across the state of Vermont.

The funding was to further Vermont's efforts to deploy a statewide smart grid and to help tackle the human dimensions of grid modernization, specifically the need for a workforce adequately trained to design, develop, install, operate, and maintain an advanced grid but also equipped to understand related challenges such as the integration of renewables, the emergence of an electrified transportation sector, and the need to imbed cybersecurity in new system designs.

This Power Systems Fellowship Program had four primary objectives:

1. to enhance multidisciplinary education and workforce development in smart grid-related fields, thus indirectly supporting deployment of Vermont's statewide smart grid;
2. to promote broader public understanding within Vermont of the need for and benefits associated with smart grid deployment;



3. to promote collaborative research between Sandia researchers and faculty at UVM and other Vermont academic institutions in smart-grid relevant disciplines; and
4. to form liaisons with private and public stakeholders across Vermont to encourage information sharing, technology transfer, and job growth in the electric power sector.

In formulating these objectives, the Steering Committee identified four key technical areas that reflect technical and programmatic synergies between Sandia and UVM.

- Smart grid
- Complex systems approaches to understanding and evolving the power grid
- Human behavioral impacts on the power grid
- Policy impacts on power grid operation and design

This effort very much recognized the fact that grid modernization requires more than technological development (although this is critical); it must include consumer engagement, policy considerations, education, and workforce training.

Achieving the goals of the grant would serve a dual purpose: they would have immediate local impact, facilitating Vermont's transition to a smart-grid state *and* they would allow Vermont to emerge as a national leader in energy transformation, an area critically important to national security.

The activities made possible by this grant (Work order #M610000767) are described in this report along with a set of recommendations for future collaborative work.

The Sandia-Vermont Partnership

The partnership between *Sandia National Laboratories* and the State of Vermont, supported by the DOE's Power Systems Fellowship Program (as described in this report,) remains an ongoing collaboration, a testament to the synergies and collaborative relations that emerged between the two partners in FY2011.

The enduring nature of the partnership reflects two underlying facts. One, both Sandia and Vermont share a common vision for the future of the electric grid, a vision that is broadly defined to include improved efficiency and advanced smart grid technologies, reduced dependence on foreign oil, limited greenhouse gas emissions, and the successful integration of new sources of renewable energy generation into the existing power system. And two, both view the partnership as an exceptional opportunity to combine their respective strengths to serve local and national interests. Specifically, Sandia brings deep expertise in power systems and energy surety (safety, security, reliability, sustainability, and cost effectiveness) to the partnership. Vermont brings a collaborative spirit and sense of openness that prevails across government agencies, private-sector energy companies, academic institutions, and nonprofit organizations. In short, Vermont—unified in its political commitment to energy transformation, united behind a statewide smart grid deployment effort and in partnership with by Sandia—has the potential (as explained below) to model systemic change in the electric sector and thus be a blueprint for the rest of the nation.

Working together, Sandia and Vermont have a unique opportunity to leverage the expertise and skills that exist in both places to drive fundamental change in the electric sector, change that translates into opportunities beyond the state of Vermont.

Vermont: A Leader of Energy Innovation

Although a small state, Vermont is at the forefront of smart grid deployment, and an emerging leader nationally in helping define, build, and test a modern, secure, and resilient grid. Several reasons explain Vermont's unique ability to serve as a national model for smart grid deployment.

To begin with, Vermont is on track to become the first state in the nation to deploy a statewide smart grid, with smart meters projected to reach 85% of Vermont's electricity customers by 2013. That effort is made possible by an American Reinvestment and Recovery Act (ARRA) Smart Grid Investment Grant of \$69.5 million (matched equally by the Vermont's 21 utilities) to upgrade the state's distribution grid with two-way communications systems and smart meters.

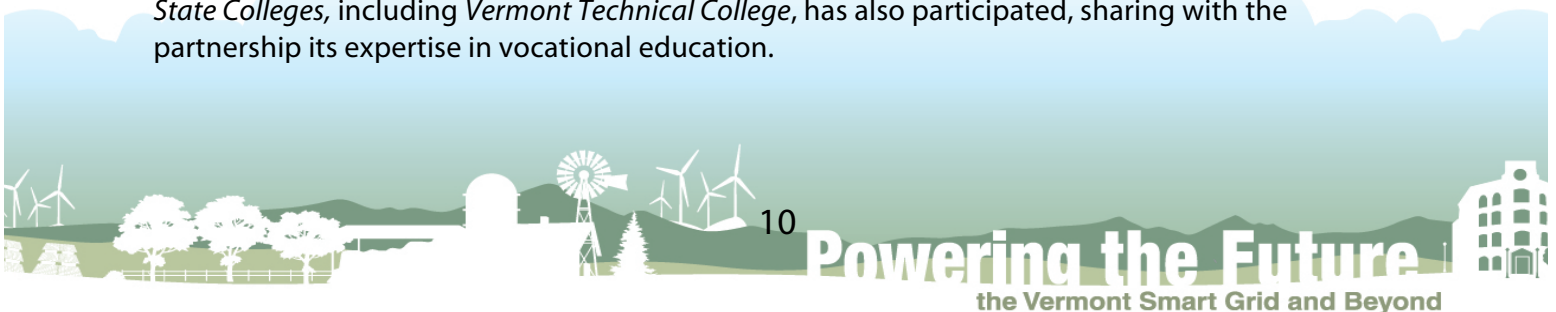
This smart grid deployment effort, known as *e-Energy Vermont*, involves the full roster of utilities working together, along with the Vermont Department of Public Service, a collaborative process that

- encourages information sharing by providing a venue for communication among the electric utilities and also the state's regulators;
- offers benefits of scale and a common procurement process for smart grid technologies;
- ensures all the utilities, regardless of size, have an equal voice in the deployment process; and
- provides an opportunity to work together on outreach and communications to the public.

Political support for e-Energy Vermont exists at all levels, with Vermont's U.S. Congressional Delegation and the Governor unanimous in their support of grid innovation, improved efficiency, and the growth of renewables. Because of such support, Vermont is already a leader in energy efficiency, ranking first nationwide in electricity efficiency gains and is the only state in the country to have a designated efficiency utility, *Efficiency Vermont*. Such commitment to a better energy future is shared by the state's vibrant and dedicated energy community, which includes (apart from the utilities) numerous dedicated and innovative nonprofits as well as private-sector energy technology companies. These organizations are working in lockstep to drive significant technological progress in the areas of efficiency, renewables, energy storage, and communications.

Moreover, Vermont is home to several academic institutions, with strengths in key areas related to energy and whose participation has been essential to the success of this project. UVM, for example, though a small public research university, has demonstrated excellence in several areas directly related to smart grid, notably complex systems, behavioral sciences, and electrical engineering. It is also committed—through its Office of Technology Commercialization and partnership with the *Vermont Center for Emerging Technologies*—to technology transfer and workplace innovation and has several centers, including the Complex Systems Center and the Transportation Research Center whose work has added value to this project.

In addition, the *Vermont Law School*, a world-renowned institution that specializes in environmental and energy law, has—through its Institute for Energy and the Environment and its Smart Grid Project—been a key participant in the Sandia-Vermont partnership. *Norwich University* has similarly brought expertise in cybersecurity and risk assessment to the project; the *Vermont State Colleges*, including *Vermont Technical College*, has also participated, sharing with the partnership its expertise in vocational education.



Sandia National Laboratories: Exceptional Service in the National Interest

Headquartered in Albuquerque, New Mexico, and with a research site in Livermore, California, Sandia is a U.S. Department of Energy-owned and contractor-operated Federally Funded Research and Development Center, one of 17 such laboratories in the U.S. that advances cutting-edge research in energy-related fields. Since 1949, Sandia has been a leader in preventing technological surprise, in anticipating threats, and in providing transformative science- and technology-based solutions to the nation's energy challenges.

Sandia also has a long history of partnering with others, believing collaboration is essential to innovation. The Labs share science and technology resources, staff, and infrastructure with partners across the U.S., encouraging its researchers to present their research publicly and welcoming faculty and students to Sandia. This collaborative approach ensures that solutions are developed in lockstep with end-user needs, accelerates the pace with which new technologies reach the marketplace, and allows well-engineered solutions to reach the places where they have the greatest impact.

Recognizing the need to meet the unique energy challenges of our 21st-century world, with its expanding electricity needs and unsustainable reliance on fossil fuels, Sandia has established the Energy, Climate, and Infrastructure Security strategic management unit. This unit supports research in renewable energy systems, climate modeling, water quality, smart grid implementation, alternative fuels, and grid security in order to

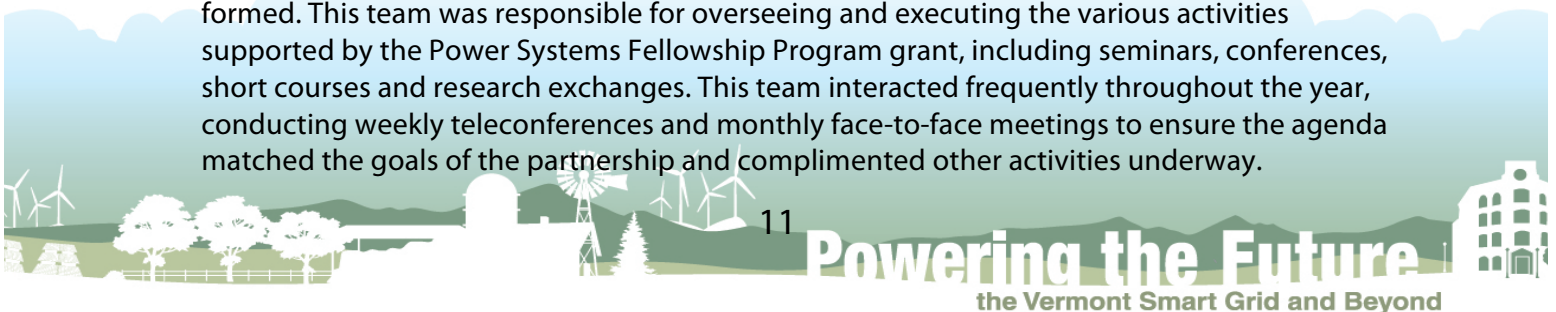
- reduce the nation's dependence on foreign oil,
- increase deployment of low-carbon power generation,
- understand the risks and help mitigate climate-change impacts,
- increase security and resiliency of the electrical grid and energy infrastructure, and
- strengthen the nation's science and technology capabilities related to energy, climate and infrastructure.

Partnerships are key to accelerating innovation, development, and successfully deploying solutions to the nation's most challenging energy problems.

Organizational Structure

To meet the objectives of the Power Systems Fellowship Program collaboration and to ensure a successful outcome for the partnership, a three-part organizational structure was put in place.

- ***Steering Committee***
A three-member Steering Committee made of representatives from Sandia, UVM, and the state's second largest electric utility, *Green Mountain Power*, was created. This committee communicated via monthly conference calls, and engaged in lengthy face-to-face meetings twice during a six-month period.
- ***Core Team***
A 12-member core team, with membership evenly split between Sandia and UVM, was also formed. This team was responsible for overseeing and executing the various activities supported by the Power Systems Fellowship Program grant, including seminars, conferences, short courses and research exchanges. This team interacted frequently throughout the year, conducting weekly teleconferences and monthly face-to-face meetings to ensure the agenda matched the goals of the partnership and complimented other activities underway.



- **Research Topics**

Four research areas—complex systems, smart grid, consumer behavior, and policy—were identified as strategically important to the project. Collectively these topics (1) reflect the complementary strengths of Sandia and UVM, (2) lend themselves to multidisciplinary research, and (3) have the potential to produce integrated, validated models of smart grid technology, consumer behavior, and related policy within a complex systems framework and to have immediate impact.

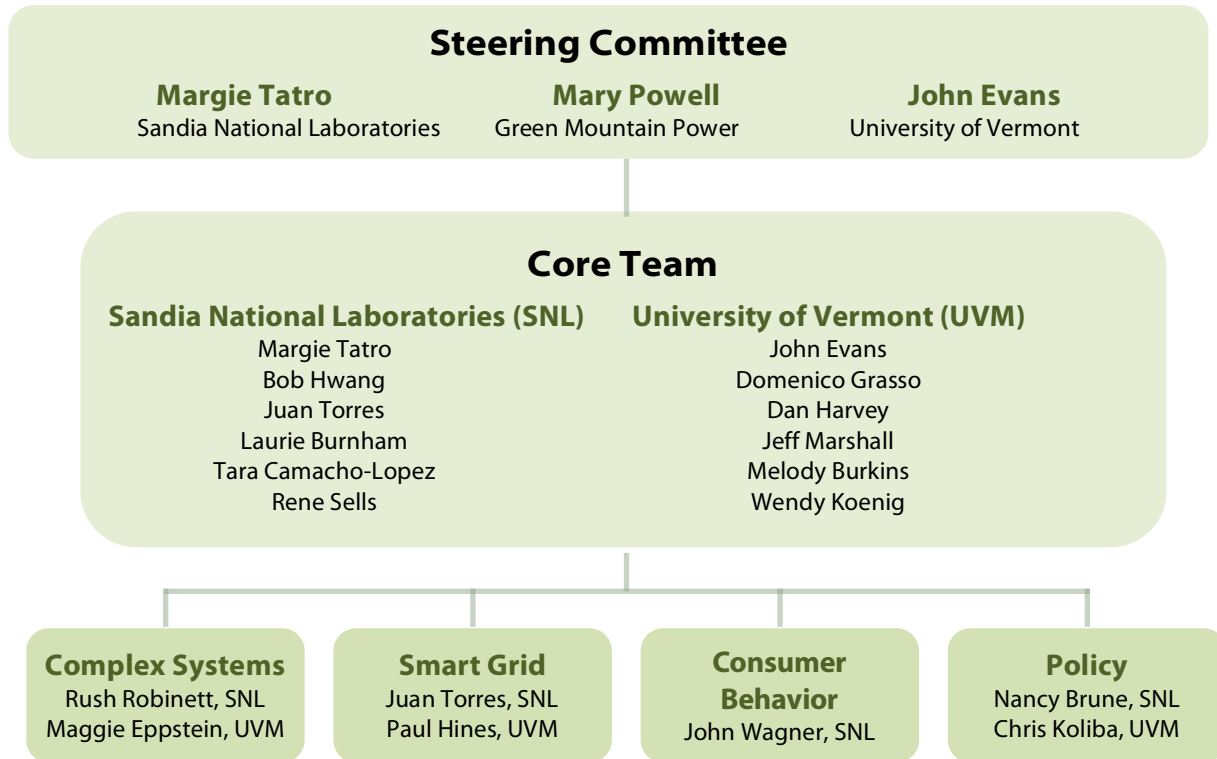
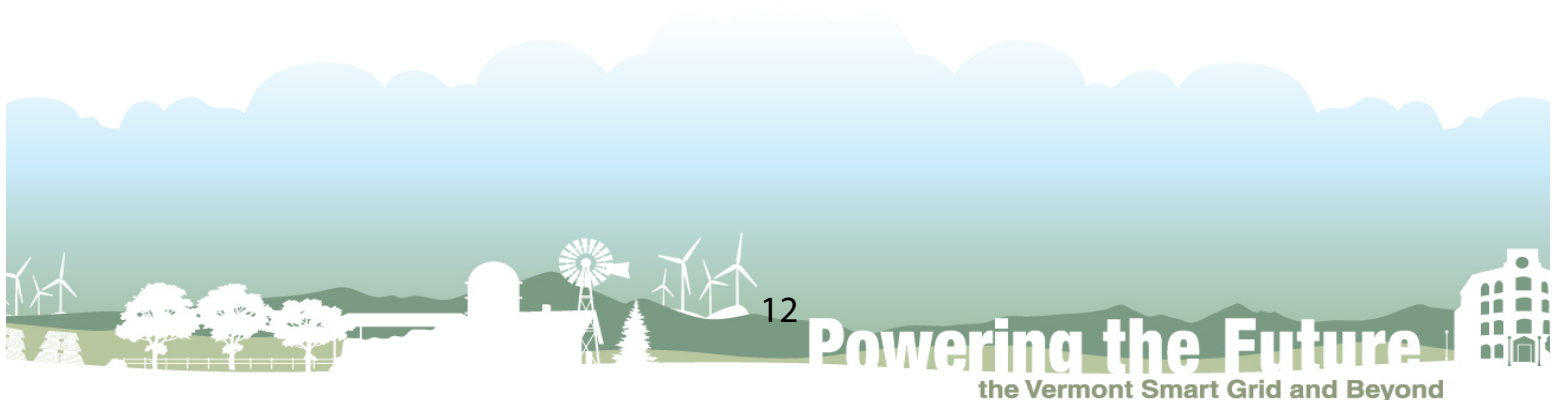


Figure 1. *Organizational Chart for the Sandia-Vermont partnership in FY2011.*

Project Activities

During FY2011, the Sandia-Vermont partnership supported a suite of activities around smart grid deployment; some were launched to help meet Vermont's immediate educational and training needs; others formed the foundation for longer-term collaborations related to smart grid research and development (R&D). Collectively, they fall into one or more of the following categories: education and training, stakeholder outreach, and collaborative research.



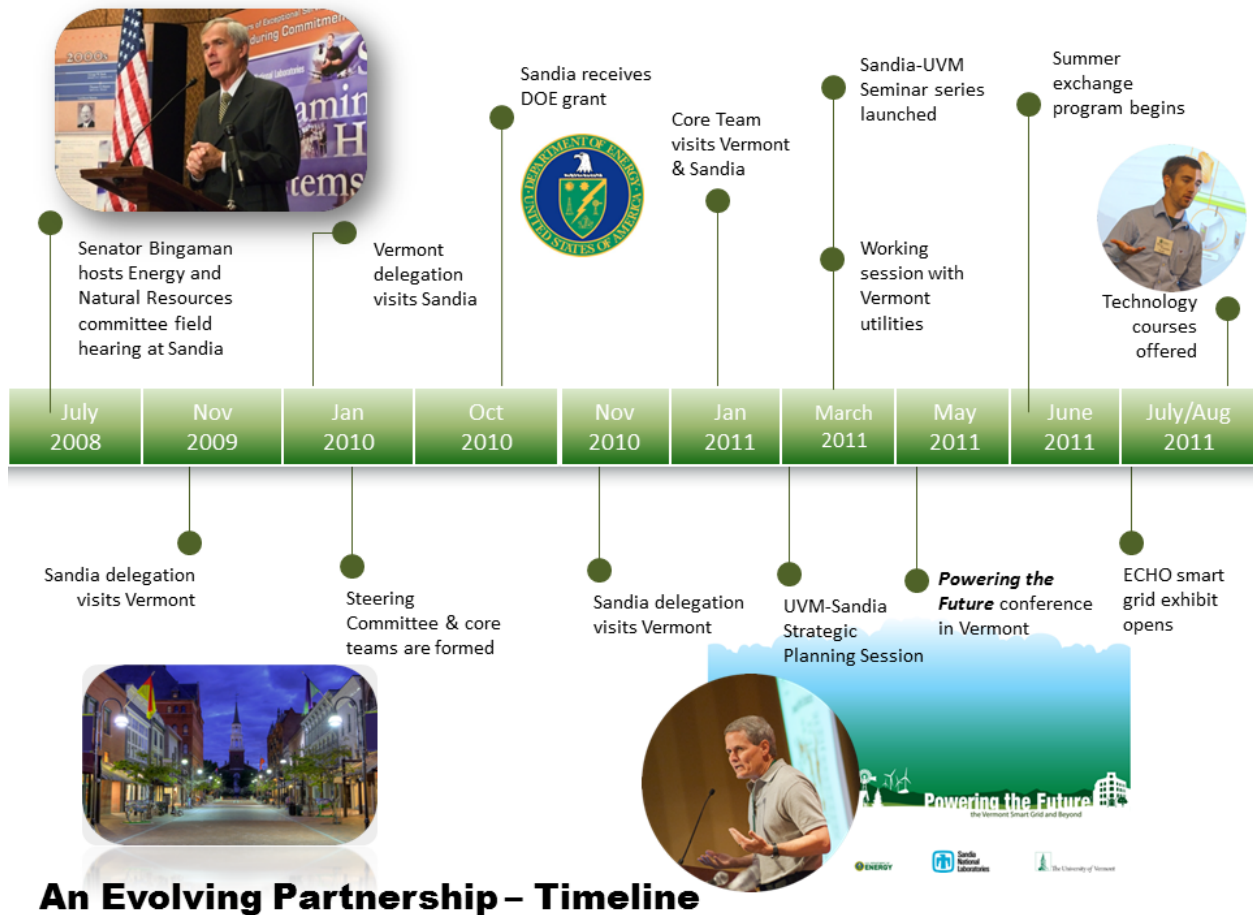


Figure 2. Timeline of the activities that helped develop and define the Sandia-Vermont partnership for energy transformation and innovation.

I. Education and Training

Powering the Future Seminar Series

Intended to stimulate student interest in the electric sector, elevate the public's understanding of the smart grid, and showcase Sandia's cutting-edge work in smart grid R&D, this seven-seminar series covered a range of timely topics, such as renewable-energy integration and supply-chain security for the grid. The series also deepened relations between Sandia and UVM by enabling the Sandia researchers who were on campus to engage in one-on-one conversations with their UVM peers, interact with undergraduate and graduate students in the classroom, and deliver a public lecture on a topic related to energy and the smart grid. The seminar series also contributed directly to students' interest in applying for a summer internship at Sandia.

As the seminars gained recognition, the number of attendees increased, with what was initially an academic audience evolving into a mixed audience of faculty, students, representatives from Vermont electric utilities as well as private-sector technology companies, and the local press.

Overall, the objectives of the series were to

- encourage cross-institutional, cross-disciplinary dialogue;
- provide a catalyst and foundation for future R&D efforts;

- provide a forum for engaging students and stimulating their interest in the electric sector;
- contribute to the public's understanding of the challenges and possibilities of transforming the state's energy sector;
- showcase Sandia's technical expertise and capabilities in areas related to smart grid; and
- continue to building trust at an institutional and personal level.

Topics and speakers for the *Powering the Future* seminar series are listed below.

Spring 2011

- March 23. *Smart Grid Challenges and Opportunities*, by Juan Torres, Manager of Energy Surety Engineering and Analysis
- March 29. *Solar Energy and Our Electricity Future*, by Charles Hanley, Manager of Photovoltaic and Distributed Systems Integration
- May 2. *Climate Change, Technology, and Global Security*, by Rob Leland, Director Climate Security

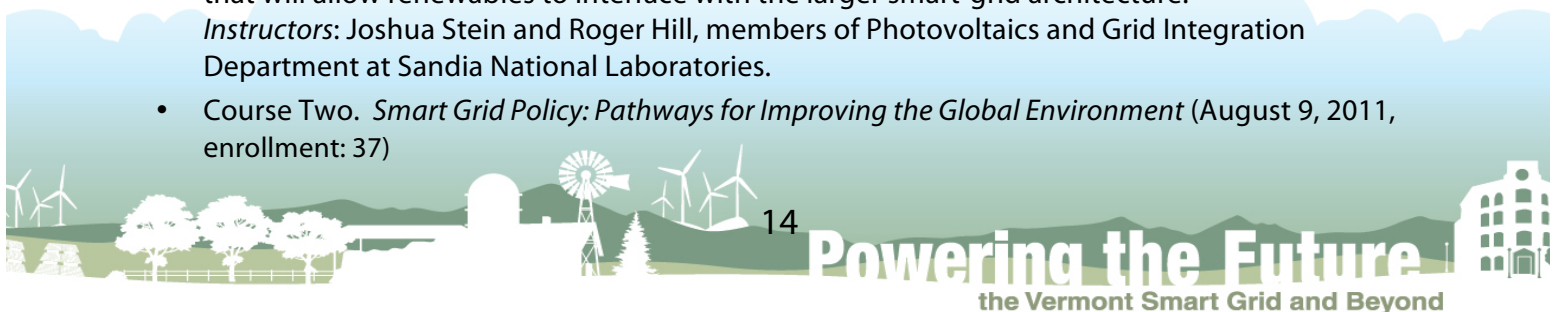
Fall 2011

- September 6. *Integrating Renewables into the Electric Grid: Where's the Storage?*, by Rush Robinett, III, Senior Manager of Grid Modernization and Military Energy Systems [postponed]
- September 13. *Smart Grid Security: Do You Know Who Your Insiders Are?*, by Bob Hutchinson, Senior Manager of Cyber Infrastructure Security
- September 21. *Stability vs Complexity: Is the Smart Grid at a Tipping Point?*, by Brian Gaucher, IBM
- October 11. *Cybersecurity of the Smart Grid: An Overview of Threats, Vulnerabilities, and Mitigation Strategies*, by Bryan Richardson, Senior Member Technical Staff, Sandia

Technology Short Courses

To support Vermont's leadership role in smart grid deployment and energy innovation, UVM, the Vermont Law School, and Sandia National Laboratories offered a series of short courses intended for a diverse audience of students and professionals. Administered by UVM's Office of Continuing Education, the courses covered key topics related to the smart grid, including the technical challenges of renewables integration and grid security, as well as policies that could facilitate statewide deployment of advanced and so-called green technologies. [For more information, see [Appendix 8](#).]

- Course One: *Renewable Energy Integration* (July 26, 2011, enrollment: 42)
This one-day course—which was structured for representatives from the utilities and energy technology companies as well as graduate students in engineering, computer science, and environmental sciences—looked at the broader energy infrastructure into which renewables are being integrated, the advances in design and components, and the smart technologies that will allow renewables to interface with the larger smart-grid architecture.
Instructors: Joshua Stein and Roger Hill, members of Photovoltaics and Grid Integration Department at Sandia National Laboratories.
- Course Two. *Smart Grid Policy: Pathways for Improving the Global Environment* (August 9, 2011, enrollment: 37)



Aimed at utilities, regulators, policymakers, investors, technology companies, and consumers interested in exploring pathways for a smart electric grid to improve the global environment, this one-day course looked at the legal, regulatory, and other policy changes that are most likely to ensure that smart grid implementation in the U.S. supports the nation's clean energy goals. The curriculum focused on smart grid benefits that go beyond basic utility business justifications, such as meter reading and outage-management automation, to address broader societal goals regarding the global environment.

Instructors: Kevin Jones and other members of the Smart Grid Research Project team at the Vermont Law School's Institute for Energy and the Environment; also Jeffrey Roark of the Electric Power Research Institute and Nancy Brune of Sandia National Laboratories.

- **Course Three. *Cybersecurity of the Smart Grid: Overview of Challenges, Implications, and Latest Mitigation Strategies*** (August 23–24, 2012, enrollment: 24)

Aimed at information technology specialists and control room engineers from utilities and energy technology companies and engineering and computer science graduate students, this two-day course provided a broad introduction to the cybersecurity of the smart grid, examining the security challenges raised by the advanced grid's two-way communications systems, wireless technologies, distributed sources of electricity and network of sensors and other smart devices, and mitigation strategies to minimize security risk.

Instructors: Bryan Richardson, senior member of the technical staff at Sandia National Laboratories and his Sandia colleagues.

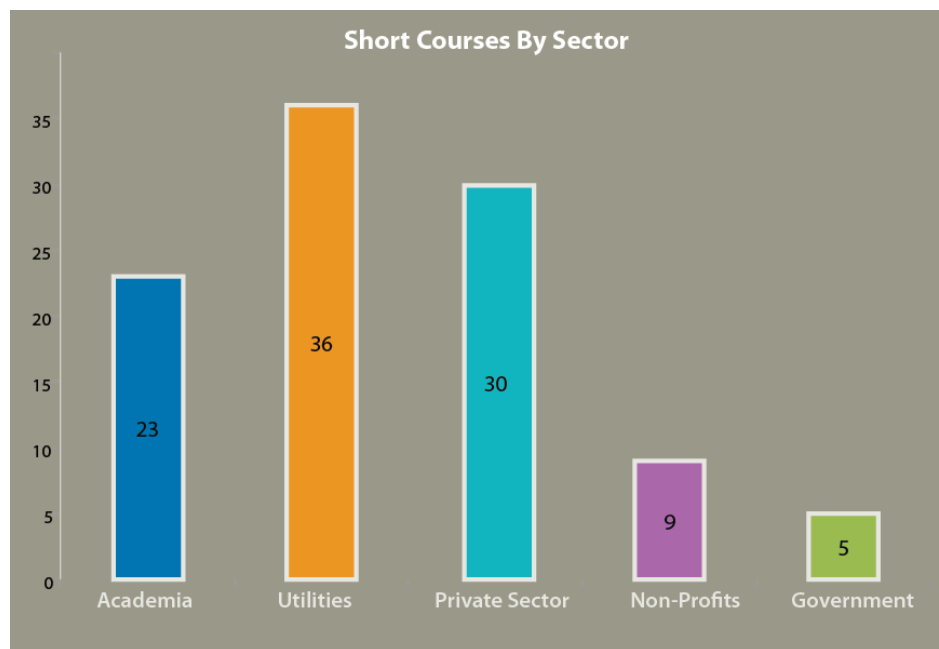
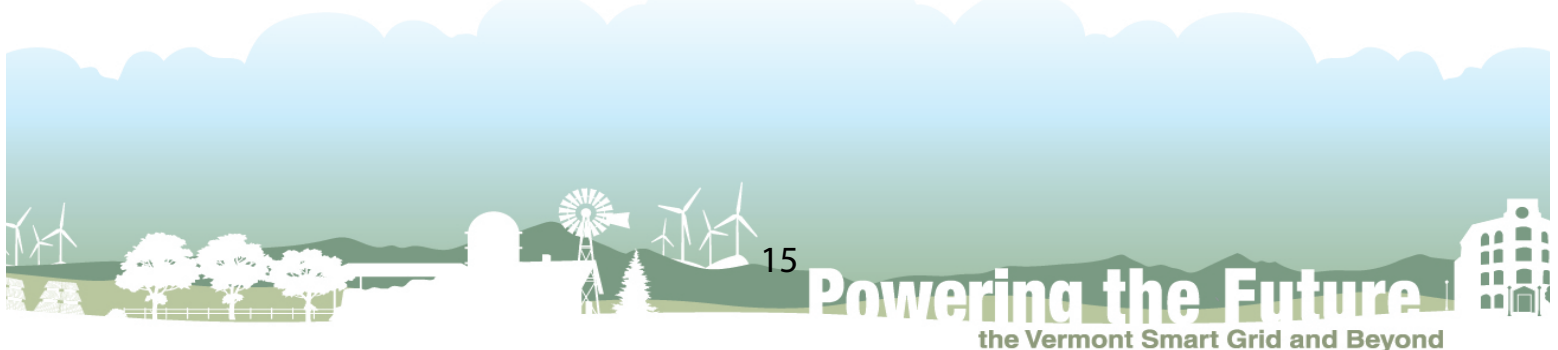


Figure 3. Technology short courses, aimed at both professionals and students, appealed to a diverse audience.



II. Stakeholder Outreach

Vermont's ability to drive change in the energy sector very much reflects the cooperative engagement of government, industry, academia, and community groups across the state, a degree of collaboration that has enabled Vermont to have impact beyond its borders, with innovative strategies, particularly in the area of efficiency, being exported to other states and countries. Similarly, the Sandia-Vermont project greatly benefitted from the cooperation that exists across sectors in Vermont by being able to solicit input from multiple stakeholders into the activities supported by this Power Systems Fellowship Program grant.

Included in the greater community are not only Vermont's electric utilities, whose smart grid deployment efforts are ahead of the national curve and whose cooperative approach is unprecedented, but private corporations, policymakers committed to energy reform in Vermont, innovative nonprofits, and renowned academic institutions.

Utilities Workshop

Members of the e-Energy Vermont team representing all the electric utilities in the state as well as the Department of Public Service [see [Appendix 4](#) for a complete list of attendees] joined representatives from Sandia, UVM, and other academic institutions for a half-day workshop to explore collaborative opportunities related to smart grid deployment and workforce development in Vermont. Specifically, the goal of the meeting was to

- identify areas of common interest and opportunities for collaborative research;
- explore ways Sandia and UVM could match their R&D expertise with the utilities' technical and practical expertise to fill gaps and further smart grid deployment across Vermont; and
- solicit the utilities' input on the following initiatives funded by DOE Power Systems Fellowship Program to ensure they meet the utilities' needs and capabilities:
 - **Powering the Future** seminar series
The utilities were asked to provide input on prospective topics and speakers and encouraged to attend the seminars.
 - **Powering the Future** stakeholder conference
Utilities' representatives at this meeting were asked to provide feedback on the draft agenda for the stakeholder conference and to be active participants in the event, both as speakers and as leaders of various breakout sessions.
 - Educational short courses
Sandia and its educational partners (including UVM, the Vermont Law School, and Norwich University) presented the group with a list of prospective short courses related to smart grid deployment intended for students, participants from Vermont's utilities, and other stakeholders with a vested interest in smart grid. Representatives from the utilities present at this meeting were asked to prioritize the list of course options, comment on course content, and offer suggestions for future courses.
 - Collaborative research
Research teams from Sandia and UVM presented overviews of their proposed collaborative work in the following topic areas: complex systems, smart grid, policy, and human behavior, in order to solicit input, feedback, and possible engagement from the utilities.

Stakeholder Conference:

Powering the Future: The Vermont Smart Grid (Burlington, Vermont, May 17–18, 2011)

More than 150 participants from across Vermont, representing utilities, colleges and universities, state and federal government officials, and private industry, attended this conference to address Vermont's efforts in statewide smart grid deployment, including security of the grid, microgrids, renewables integration, consumer interactions, and workforce training. Over the course of two days, attendees examined best practices that are driving energy reform in Vermont and explored ways to bring those efforts to the national stage. [Read the [conference report](#).]

On the first day, numerous speakers called attention to Vermont's progress in statewide smart grid deployment and related fields, including telecommunications upgrades, renewables integration, microgrid installations, and electric transportation, producing what amounted to a collective vision for energy optimization in Vermont. Plenary speakers included U.S. Senators Bernie Sanders (Vermont) and Jeff Bingaman (New Mexico) (by video), Vermont Governor Peter Shumlin, UVM President Daniel Fogel, Sandia Vice President Rick Stulen, and DOE Office of Electricity Delivery and Energy Reliability Assistant Secretary Patricia Hoffman.

On the second day, conference attendees participated in breakout sessions on six topics: consumer interactions, policy and governance, energy management, modeling and informatics, workforce development, and cybersecurity. For a summary of those breakout sessions, along with a set of recommendations, see [Appendix 7](#).

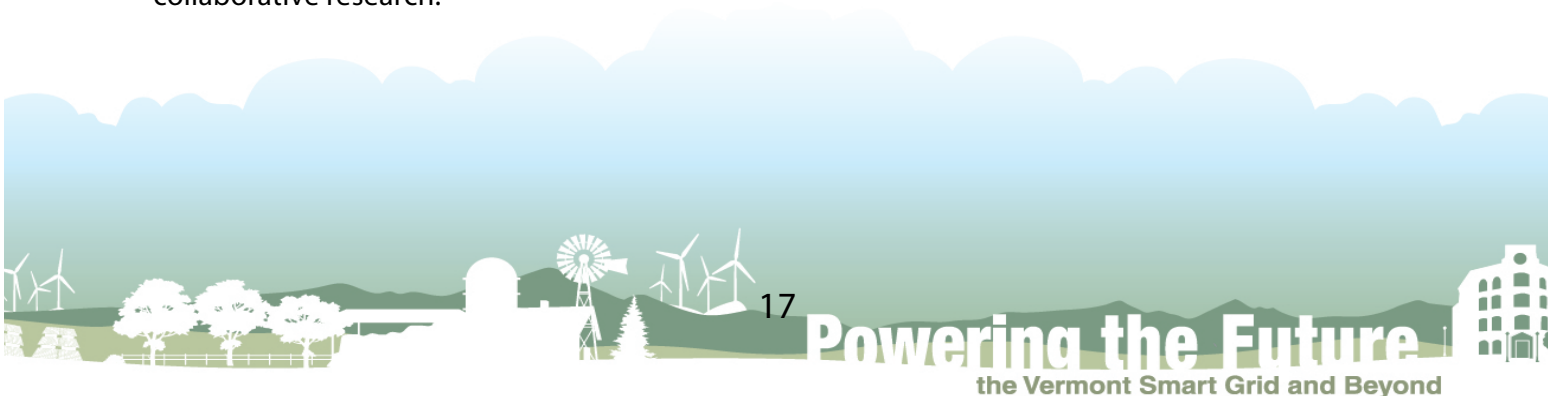
The conference also had a strong educational component. In addition to including undergraduate and graduate students from UVM, who took notes and produced a conference report, high school students from the Vermont State Science and Math Fair presented posters on a variety of energy-related topics.

To prepare for the workshops, the Sandia-Vermont Core Team held weekly teleconferences and also conducted several face-to-face meetings to ensure the agenda matched the goals of the partnership and complimented other activities underway.

Overall, the conference served to

- draw attention to the partnership between Sandia and Vermont,
- showcase Vermont's emergence as a national leader of energy innovation and smart grid deployment,
- create a platform for information sharing and exchange of best practices, and
- engage the next-generation smart grid workforce.

At the end of the two-day conference, participants had a more complete understanding of Vermont's competitive advantages in developing, testing and exporting best-practices for smart-grid deployment and grid transformation and also had begun to build relationships that would prove crucial to the success of other project-related activities, included short courses and collaborative research.



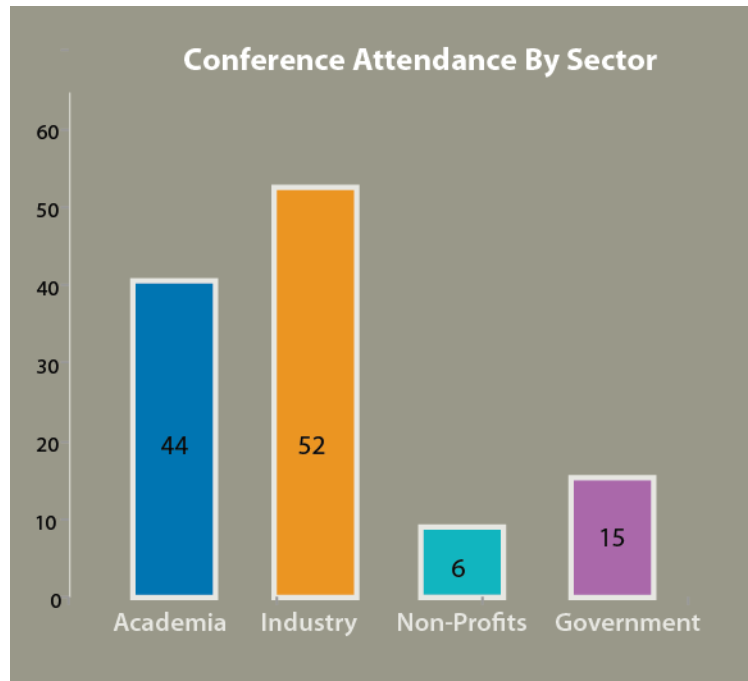


Figure 4. *Powering the Future* conference drew more than 150 participants from multiple sectors.

ECHO Science Center

Sandia, UVM, a group of energy technology companies, the e-Energy Vermont Communications Working Group (a subgroup of Vermont's 22 utilities), and the ECHO Lake Aquarium and Science Center jointly developed and designed an interactive smart grid display. Targeted at the general public and developed with the help of engineering students from UVM, the project had two primary purposes: (1) to educate consumers about the smart grid and (2) to collect data on visitors' understanding of the smart grid, thus informing future research in consumer-related fields.

Designed to be interactive, the display included demonstrations related to electricity and personal one-on-one encounters with the student interns that enabled visitors to ask questions and engage in hands-on activities.

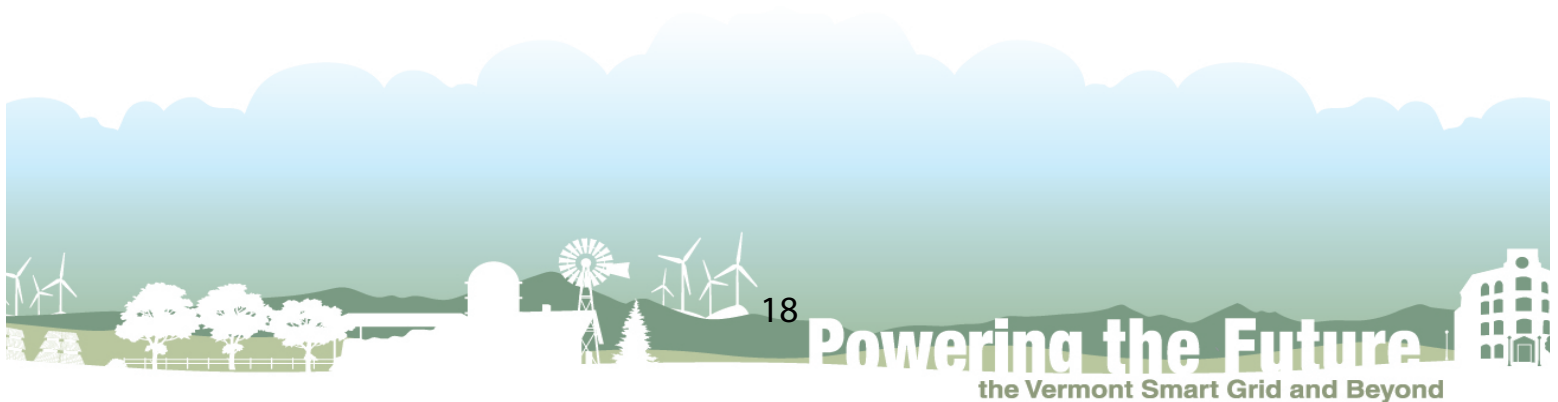




Figure 5. University of Vermont students engage ECHO Science Center visitors in a game of "Smart Grid Jeopardy."

The activities associated with this project, which took place between June and August of 2011 are listed below [details and supporting documents can be found in [Appendix 9](#)].

- The interns participated in a five-day intensive orientation at ECHO (June 13–17) followed by guided mentoring over the course of ten weeks. Interns spent time training as general educators on ECHO's exhibit floor, researching and developing outreach programming, and delivering at least one daily program.
- The interns visited six of Vermont's utilities & transmission companies (Burlington Electric Department, Vermont Energy Investment Corporation/Efficiency Vermont, Vermont Electric Cooperative, Vermont Electric Power Company, Central Vermont Public Service, and IBM) to get background information about the e-Energy Vermont. They also met with energy experts, renewable energy companies, consulting agencies, educational outreach programs, government agencies, and technology companies to determine if there were resources to be borrowed and solicit ideas for activities; they also toured facilities to see how a utility works.
- The display was a collaborative undertaking with the e-Energy Vermont Communications Working Group, resulting in the creation of activities and demonstrations related to three key topic areas, defined with members of the Smart Grid Communications Group: peak power, energy basics, and renewable energy. The interns continued to engage with the group twice a month throughout the course of the project.
- ECHO provided desk space and resources for interns to develop outreach materials and provided floor space within the facility to deliver programs and display materials.
- ECHO and a UVM researcher conducted a small evaluation study to document visitors' general understanding and questions about smart grid technology, as well as the impact of outreach programming on participating visitors' interest and understanding of smart grid technology.
- With ECHO guidance, the interns created a display on ECHO's science workbench exhibit. The display provided a general overview of Smart Grid technology in the form of information panels, artifacts, and audiovisual content.
- The interns also created progress journals—documenting their training, program and display development, and interaction with ECHO guests—and contributed to two blogs.

- The display was visible to 35,000 museum visitors, 847 opted to engage in one of the daily encounters.
- The interns were highlighted in the *Burlington Free Press*.

e-Energy Vermont Communications Working Group

Representatives from Sandia participated in bimonthly e-Energy Vermont Communications Working Group meetings, which represents Vermont's utilities and the Vermont Department of Public Service, to discuss consumer outreach, exchange information related to smart meters and other dimensions of the smart grid, and help plan the smart grid exhibit, including hiring student interns to develop the exhibit at Vermont's ECHO Lake Aquarium and Science Center.

III. Collaborative Research

Research Topics:

The core team overseeing this Power Systems Fellowship Program project identified four technical areas that have the potential to significantly impact smart grid deployment in the U.S. and also reflect both partners' institutional strengths. These areas, and the technical leads from each institution assigned to each research area are listed in Table 1.

Table 1. Collaborative Research Topics Related to the Smart Grid

Research Topic	Technical Leads from Each Institution
Complex systems	Rush Robinett , III, Senior Manager of Grid Modernization and Military Energy Systems, Sandia, and Maggie Eppstein, Professor of Computer Science at UVM
Smart grid	Juan Torres, Manager of Energy Systems Analysis, Sandia, and Paul Hines, Professor of Engineering, UVM
Policy	Nancy Brune, Member of the Technical Staff, Sandia, and Christopher Koliba, Professor of Public Policy, UVM
Human behavior	John Wagner, Manager of Cognitive Modeling, Sandia, and Stephen Higgins, Professor of Psychiatry, UVM ¹

To bring focus to those areas and build research collaborations to support the Power Systems Fellowship Program project, the Sandia-Vermont Core Team held a daylong meeting on February 18, 2011, at UVM. The technical leads from both institutions discussed topics of complimentary interest and explored collaborative research ideas related to the smart grid that could be implemented by the summer of 2011.

In considering possible research projects, the following questions were posed:

1. Does the research reflect the overall mission of the partnership?
2. Does it address an identified need or gap?

¹ Diann Gaalema, a postdoctoral fellow in psychiatry at UVM has since replaced Stephen Higgins.

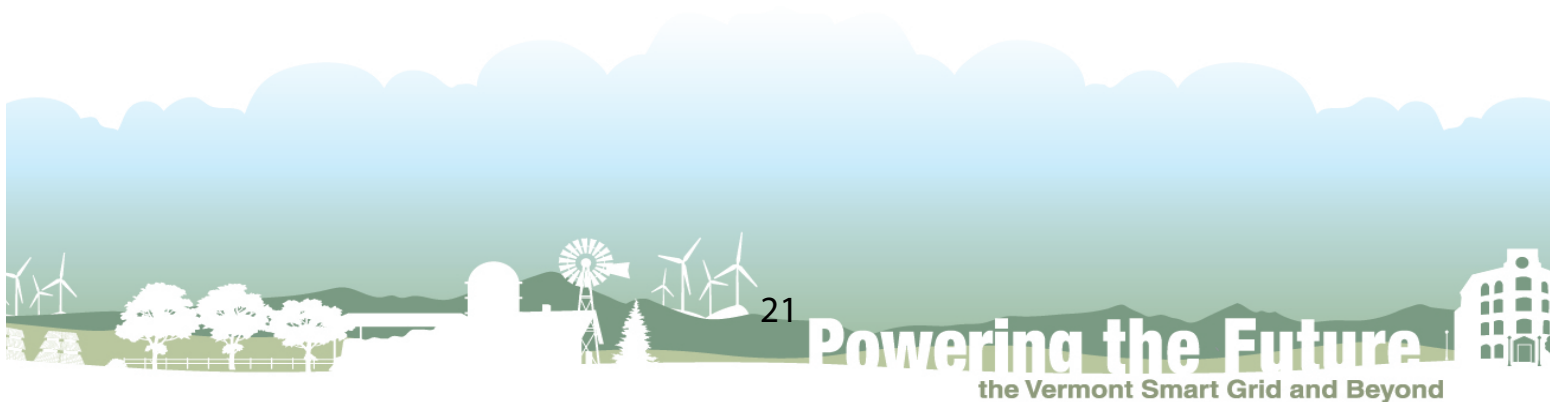


3. Does it reflect individual and institutional strengths and talents?
4. Does it have a multidisciplinary focus?
5. Does it lend itself to a collaborative process and can it accommodate students?
6. Does it have a defined scope and will it likely produce tangible deliverables within the time scope of the grant?
7. Will the research be relevant to Vermont but also have national impact?

Student and Faculty Exchange

Following a competitive selection process, 9 UVM students were awarded stipends to spend 10 weeks during the summer of 2011 at Sandia, where they conducted original research related to the smart grid. The intent of this internship was to promote career interest in the power sector and to expose students to the world-class research facilities at Sandia. [See [Appendix 11](#) for a compilation of their research projects.]

Eight faculty members, including the four technical leads, also spent varying amounts of time at Sandia working on research projects and furthering collaborations.



Research Projects

The research that resulted from this first year of collaboration between Sandia and UVM, including student work, is sorted by category and listed as follows.

Table 2. Collaborative Research Projects launched by Sandia and UVM in 2011

Research Category	Research Project Focus Areas
Smart grid performance	<ul style="list-style-type: none">Modeling cascading electric grid failureCommunications infrastructure for renewables in a microgridPerformance modeling to optimize the operations and maintenance of photovoltaic power plantsModeling the electric load curve of plug-in hybrid electric vehicle (PHEV) charging systems and its impact on underground cables
Consumer decision making	<ul style="list-style-type: none">Role of social media in generating public interest in smart grid issuesPredicting PHEV penetration by linking demographics to consumer purchase preferencesSurvey in Vermont of opinions regarding smart grid technologies and deployment
Policy analysis	<ul style="list-style-type: none">e-Energy Vermont Collaboration: a case study of private-public partnerships, regulatory subsystems and statewide smart grid deployment.Smart Grid governance networks and policy issuesImpact of smart grid policies on consumer's energy consumption behavior

Conclusion: Making an Impact

Over the course of the past year, Sandia and UVM have had a singular opportunity to promote education, training and research related to smart grid deployment in the state of Vermont. The results of that effort speak for themselves: the community of stakeholders driving energy innovation in Vermont, a group that includes students, researchers, policymakers, CEOs, and power engineers, has come together to exchange ideas, sharpen its technical skills, embark on important research and collectively envision a better energy future, not only for the state of Vermont but for the entire nation.

The tools, experience and technology developed by the partnership could help push the nation toward successful implementation of a 21st-century energy system.

Moreover, the effort begun here—with funding from DOE's Power Systems Fellowship Program—will persist and expand, with Vermont and Sandia continuing to engage in research that is essential to the national development of the smart grid and transformation of the electric sector.

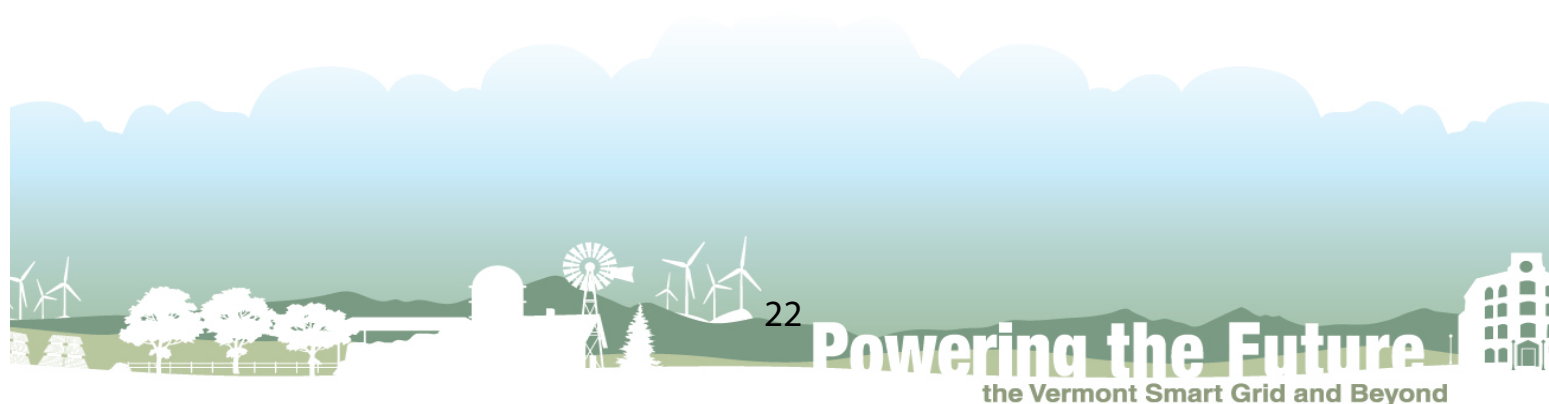
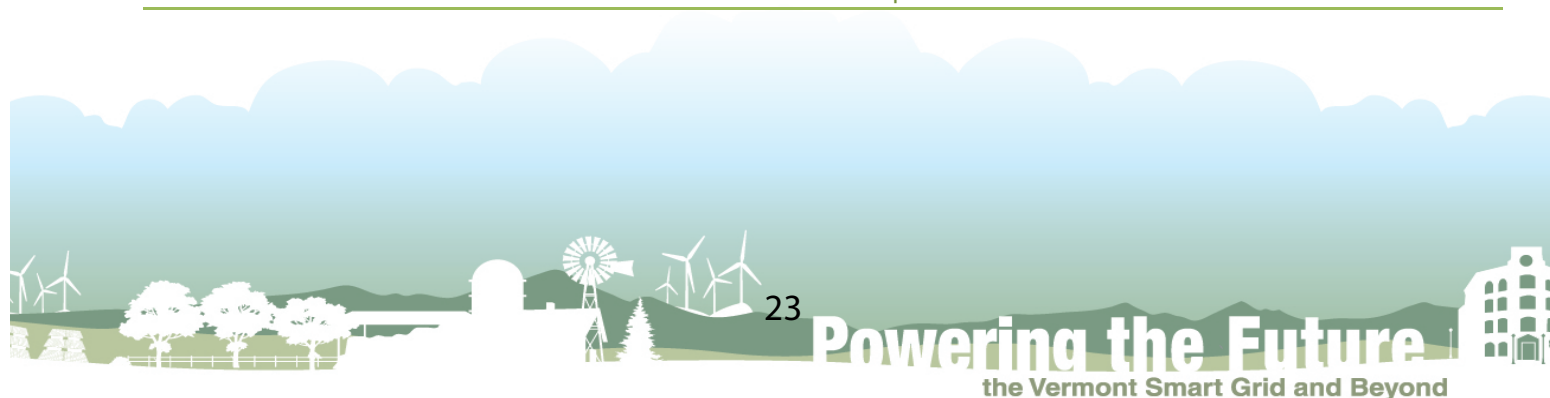


Table 3. Jobs Created and/or Supported by the DOE Power Systems Fellowship Program

Institution	Activity	Number Employed/Supported
University of Vermont	Student research internships at Sandia	6 undergraduates 3 graduate students
	Faculty exchange	8 faculty
	Continuing education: Technology short courses	2 staff members
Vermont Law School	Smart grid policy short course	2 faculty 3 law students
ECHO Lake Aquarium and Science Center	Smart grid display	2 undergraduates
Sandia National Laboratories	Organizational and project support (including education and training; stakeholder outreach and research.)	22 technical staff 4 laboratory staff 1 student intern
Total 53		

Table 4. A Collaborative Effort: Stakeholders in the Vermont-Sandia Partnership

Research and Academic Institutions	State Government	Utilities	Private Sector Companies	Nonprofit institutions
<ul style="list-style-type: none"> • Sandia National Laboratories • University of Vermont • The Vermont Law School • Norwich University • Vermont State College System • Champlain College 	<ul style="list-style-type: none"> • Office of the Governor of Vermont • Department of Public Service • Department of Commerce 	<ul style="list-style-type: none"> • Vermont Electric Power Company • Green Mountain Power • Central Vermont Public Service Corp. • Burlington Electric Department • Vermont Electric Cooperative • Vermont Efficiency Investment Corp. 	<ul style="list-style-type: none"> • AllEarth Renewables • Alteris Renewables • Control Technologies • GroSolar • Draker Laboratories • IBM • NRG Systems • Omega Optical • SBElectronics 	<ul style="list-style-type: none"> • ECHO Lake and Aquarium Science Center • Renewable Energy Vermont



Appendix 1: UVM-Sandia Strategic Planning Session

Meeting Summary- February 8, 2011

Purpose

A planning session was held at UVM to bring Sandia National Laboratories and UVM researchers together to identify areas of common interest and also prospective research topics related to smart grid development and deployment.

Partners

Sandia National Laboratories, Vermont educational institutions, Vermont utilities and supporting industries.

Research Areas Identified (along with primary components)

1. **Workforce Development** (for linemen, engineers, managers, lawyers)
2. **Smart Grid** (control, architecture, security, materials, distributed generation and storage, CO₂ sequestration)
3. **Complex Systems** (modeling, both design and implementation; agent-based models cascading failure evolutionary algorithms self-healing networks multiscale modeling)
4. **Policy** (governmental regulations, legal issues)
5. **Behavior** (psychology, incentives, social influences)
6. **Uncertainty** (sensitivity, verification, validation, reliability, optimization)

1. Academic Programs and Degrees in Vermont Related to Smart Grid

University of Vermont: School of Engineering

- Graduate Certificate in Energy Systems
- Graduate Certificate in Complex Systems

Vermont Law School: Institute for Energy and the Environment

- Energy Summer Session
- Certificate in Energy Law

Vermont Technical College: Electromechanical Engineering Technology

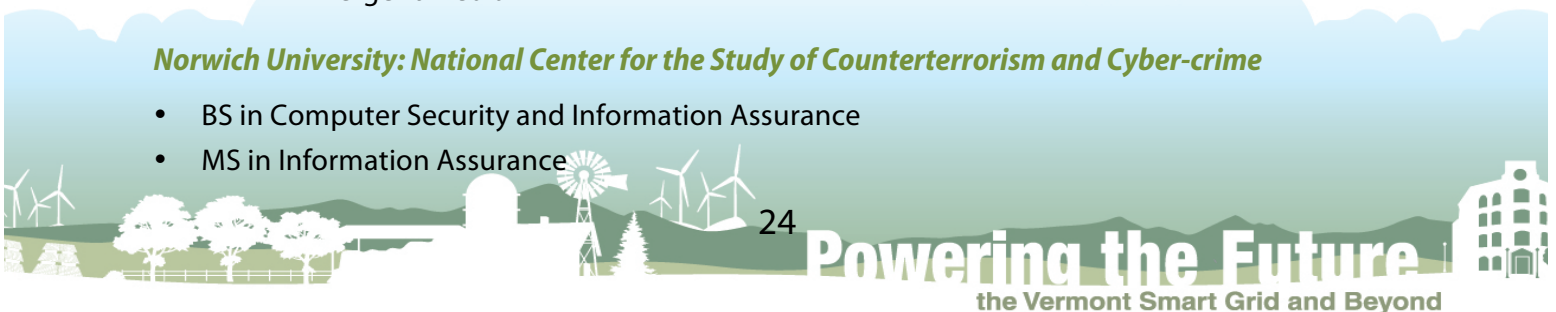
- BS in Electromechanical Engineering Technology

Champlain College: Emergent Media Center

- MFA in Emergent Media

Norwich University: National Center for the Study of Counterterrorism and Cyber-crime

- BS in Computer Security and Information Assurance
- MS in Information Assurance



2. Smart Grid: Architecture, Security, and Control

High-Level Goal

Harness and develop smart grid technology to produce better outcomes in the national electricity infrastructure in terms of improved reliability and reduced emissions, while minimizing economic costs.

Themes and Ideas

- **Optimal decision making**
 - Design automatic controllers (control agents) that can self-organize to produce improved outcomes, coordinating their actions with human agents (operators, customers, etc.)
 - Harness high performance computing to turn terabytes of smart grid data into clear, useful information for operators.
- **Complex systems methods.** Move beyond a narrow focus on short-term outcomes to think broadly about how smart grid will fit into society at large.
- **Link to social sciences.** The smart grid must enable better outcomes for human beings, requiring constant interaction with social-science tracks.
- **Resiliency.** The smart grid needs to meet its goals in the face of volitional attacks and random failure (cybersecurity and physical security.)
- **New technology** for better smart grid outcomes: battery chemistry, electrolysis, solar cells, robotics, etc.

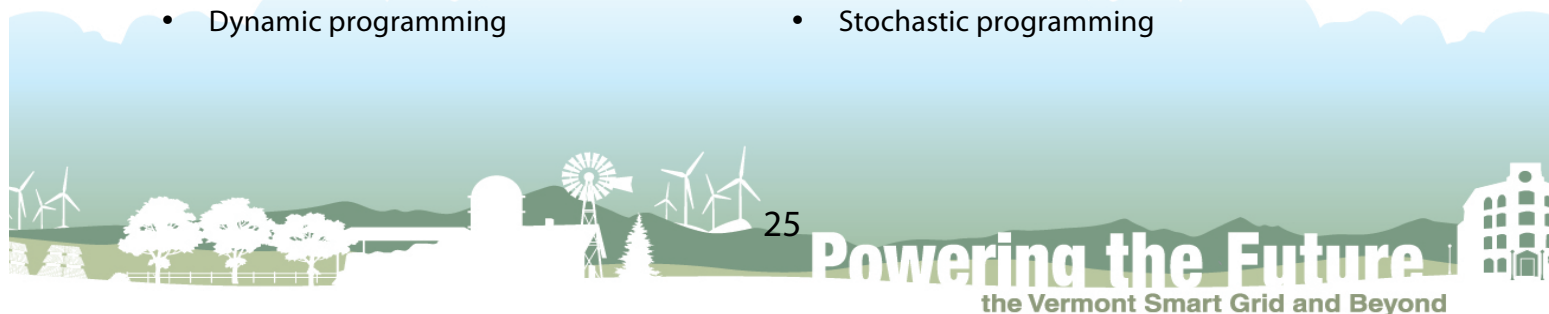
3. Complex Systems Approaches

High-Level Goals

- Take a broad systems-view of the problems associated with smart-grid
- Acknowledge nonlinear, dynamic, and localized interactions at multiple scales resulting in self-organized patterns with feedbacks that may be stabilizing or destabilizing
- Use nature-inspired computational algorithms to tackle complex problems in prediction, optimization, pattern recognition, etc.
- Use integrative methods to bring together studies in behavior, policy, electric supply and demand, grid performance, etc.

Methodologies

- | | |
|------------------------------|----------------------------------|
| • Agent-based models | • Complex network analysis |
| • Evolutionary algorithms | • Nonlinear and adaptive control |
| • Artificial neural networks | • Thermodynamics |
| • Dynamical systems theory | • Hamiltonian mechanics |
| • Dynamic programming | • Stochastic programming |



Examples

- Find k-way contingencies in grid that result in cascading failures
- Apply behavior-informed agent-based models of consumer response to different policies
- Predict grid infrastructure needs in response to consumer behaviors
- Use interactive web tools to engage public and change behaviors
- Design networked microgrids

4. Policy: Analysis of Smart Grid Governance Networks

Research Themes

- **Formation and adaptation** of smart grid governance networks (SGGNs)
- **Design and operation** of SGGNs
- **Performance and accountability** of SGGNs
- **Policy tool calibration** to behavioral and governance attributes

Research Settings

- Smart grid institutional infrastructure in Vermont and eventually other states

Methods

- **Agent-based models** of critical action arenas of SGGNs
- **Agent-based models** of consumer behavior responses to policy interventions
- **Complex system dynamic models** of financial, human, and political capital flows
- **Multicriteria analysis** of decision heuristics of key stakeholders
- **Comprehensive case studies** of smart grid institutional governance infrastructure
- **Mediated modeling** involving regulators and industry to design decision supports and policy framework (regulatory and incentives)
- **Decision support & performance management systems** for regulators and industry
- **Governance informatics platform development** to build smart grid situational awareness

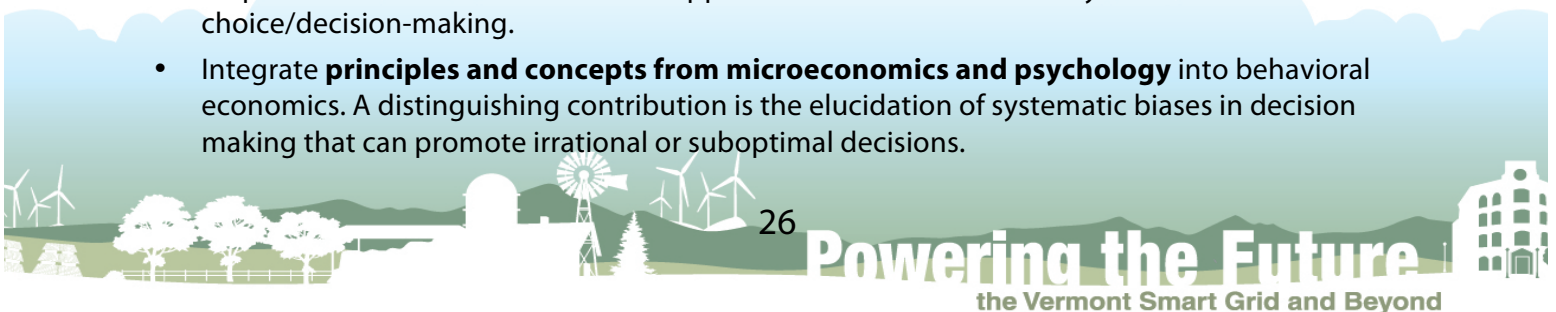
5. Behavior: Human Decision-Making and the Smart Grid

High-Level Goal

To better understand: (a) how people make decisions about energy consumption in households and small businesses and (b) how that knowledge can be used to develop effective interventions.

Themes and Ideas

- Emphasize a **behavioral economics** approach that is also informed by other theories of choice/decision-making.
- Integrate **principles and concepts from microeconomics and psychology** into behavioral economics. A distinguishing contribution is the elucidation of systematic biases in decision making that can promote irrational or suboptimal decisions.



- Investigate **how such biases are expressed** in the area of energy consumption, and the mediating or moderating influences of socio-demographic, attitudinal, and situational variables.
- Apply **intervention development and testing** to manipulating choice antecedents (e.g., information, defaults, framing, prompting, personal and public commitments, normative influences) and consequences (e.g., feedback, incentives) to increase conservation in household/small-business settings.
- Use **diffusion-of-innovations theory** to guide efforts to scale and disseminate knowledge.

6. Uncertainty Quantification

High-Level Goal

To gauge the effect of system/model uncertainties on model predictions

Themes and Ideas

- Quantify **variability** (“aleatory uncertainties”) arising from fluctuations in demand load and electrical supply, node and transmission line failures
- Quantify **incomplete knowledge** (“epistemic uncertainties”) about the future or about validity of models, e.g., consumer response to incentives
- Utilize uncertainty characterization to determine requirements for **grid resiliency**
- Examine **sensitivity** of agent-based model predictions to input and model uncertainties of different types. Is sensitivity different under different load/supply conditions? How does sensitivity change under conditions where part of the grid has failed?
- **Optimize** grid design for robustness with minimal cost.

Activities and Targets

Feb–March 2011: preliminary meetings between UVM, Sandia, utilities

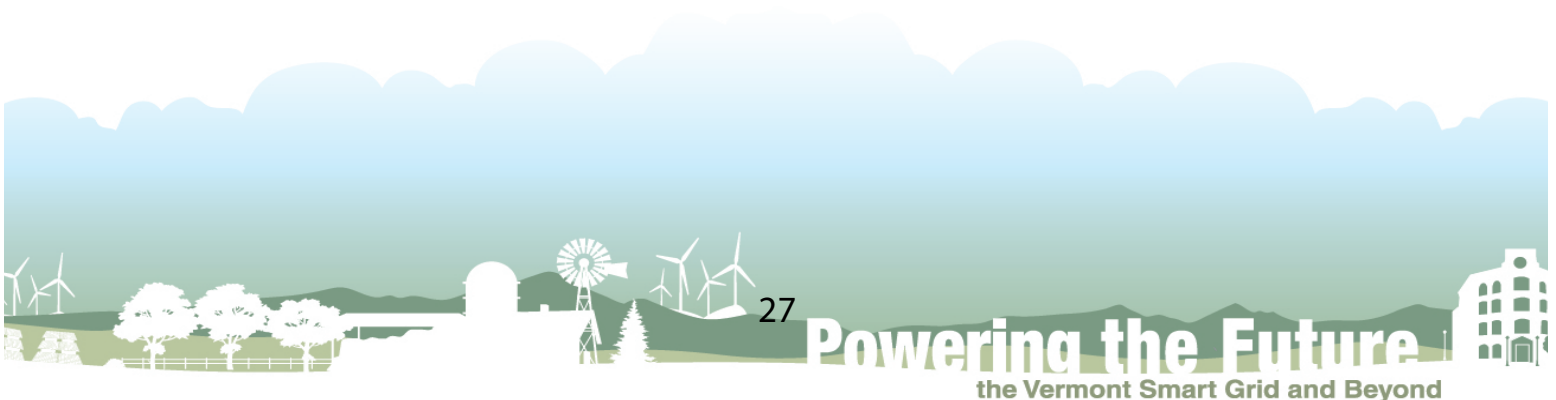
May 2011: Stakeholders’ Workshop

June–August 2011: UVM–Sandia research exchanges

Summer 2011: Sandia short courses

Spring 2011 & Fall 2011: Sandia energy seminars at UVM

September 2011: Wrap-up meeting in Washington, D.C.



Appendix 2: e-Energy Vermont Meeting to Explore Collaboration

Meeting Invitation for March 22, 2011

Representatives from Sandia National Laboratories (Sandia) and the University of Vermont (UVM) invite members of the e-Energy Vermont team to join them in a half-day discussion to explore collaborative opportunities related to smart grid deployment and workforce development in Vermont. Specifically, the goal of the meeting is to

- identify areas of common interest and also opportunities for collaborative research involving people from Sandia, UVM, and the utilities;
- explore ways Sandia and UVM can match their R&D expertise with the utilities' technical and practical expertise to help fill gaps and further smart grid deployment across Vermont; and
- solicit the utilities' input on specific tasks described in the *DOE Power Systems Fellowship Proposal* awarded to Sandia to work with the University of Vermont (and others) on the following educational and workforce-development initiatives.

1. **Collaborative Research:** Teams co-led by Sandia and UVM researchers have formed around the following four topics, each of which bears a significant relationship to smart grid deployment.

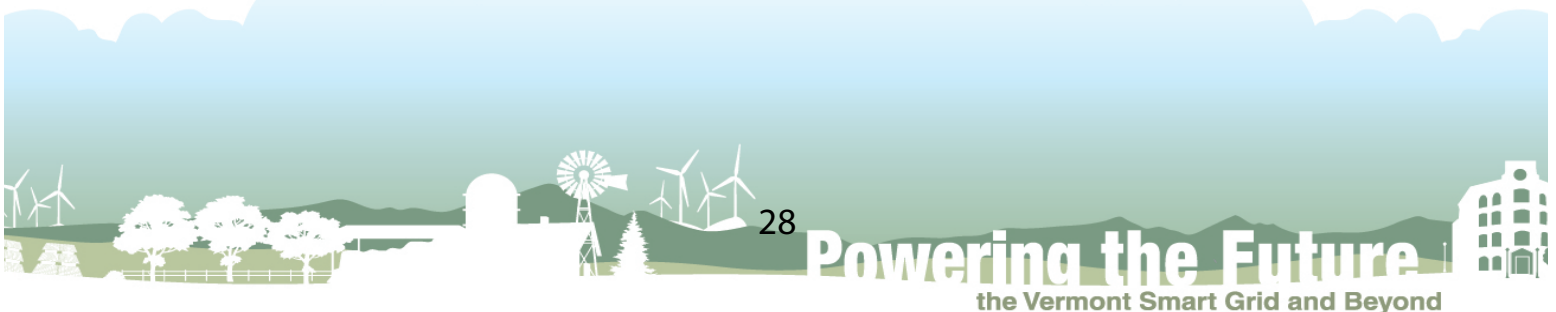
- Complex systems
- Policy
- Smart grid
- Human behavior

At the meeting, the research teams will present a preliminary overview of their collaboration ideas, soliciting input, feedback, and possible engagement from the utilities.

2. **Educational short courses:** Sandia and its educational partners (including UVM, the Vermont Law School, and Norwich University) have compiled a list of prospective short courses on topics related to smart grid deployment. These courses are intended for participants from Vermont's utilities, as well as for students and other stakeholders with a vested interest in smart grid. *Representatives from the utilities who are present at this meeting will be asked to prioritize the list, comment on course content and offer suggestions for future courses.*

3. **Seminar series:** Sandia and UVM are collaborating on a seminar series titled "Powering the Future" to be held in the spring, summer, and fall of 2011. These seminars are open to the public and *it is hoped that the utilities will participate.*

4. **"Powering the Future: The Vermont Smart Grid and Beyond":** On May 17–18, 2011, UVM and Sandia will convene a gathering of Vermont stakeholders to discuss smart grid implementation and energy innovation in Vermont and to explore opportunities for the state—the first to deploy a statewide smart grid—to become a national leader in smart energy systems. Topics (with opportunities for discussion) will include smart grid technologies, energy security, job opportunities, and partnerships and policies to grow our local economies and engage our communities. *A draft agenda for the workshop will be shared at this meeting, with participants asked for their feedback.*



Background Information

In the fall of 2010, the Department of Energy provided a grant to Sandia National Laboratories to work with stakeholders in Vermont (including UVM, the utilities and others) on issues related to the deployment of a statewide smart grid, including the work force needed to implement and sustain such a grid, the security implications of an intelligent grid, the advantages to both residential and business consumers, and the need to better understand the complex interactions that will arise in such an integrated system.

Both Sandia and Vermont bring unique but complementary strengths to the project. Sandia has a wealth of expertise, facilities and leadership experience, with an international reputation for excellence in science, technology and engineering R&D, a focus on energy and infrastructure assurance and a commitment to workforce development.

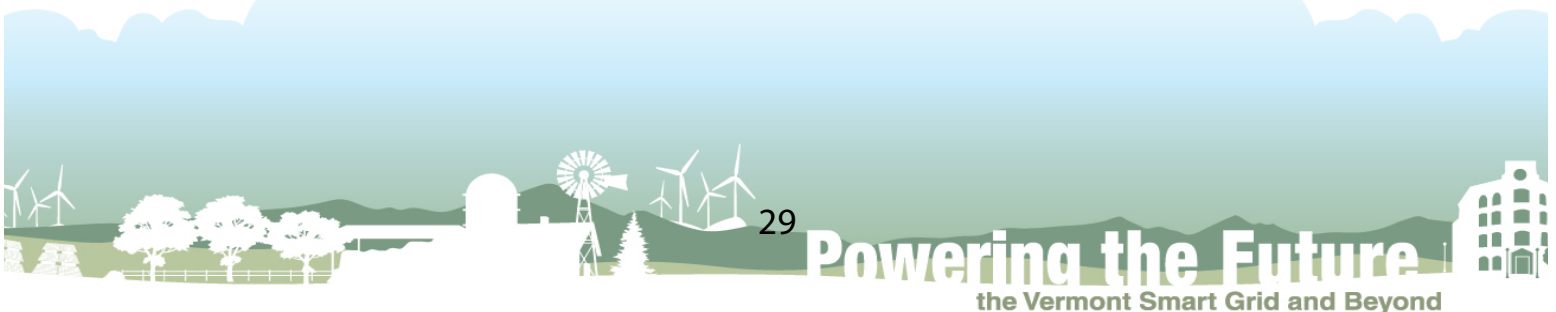
UVM—the state's land grant institution and sole research university—has a demonstrated commitment to education, research, technology transfer and commercialization, and innovation. In 2010, UVM also announced its long-term commitment to developing world-class, transdisciplinary research programs, or "Spires of Excellence," in complex systems; neuroscience, behavior, and health; and food systems. Two of these—complex systems and neuroscience, behavior, and health—are integral to the simulations, modeling, and behavioral studies at the core of 21st century smart grid research and implementation. UVM is also home to several research centers, including one of only ten U.S. Department of Transportation National University Transportation Centers, the James M. Jeffords Center for research and policy; the Vermont Advanced Computing Center; and Vermont EPSCoR.

In addition, more than any other state in the nation, Vermont has forged effective partnerships among policymakers, government agencies, private corporations, nonprofit advocacy groups, educational institutions, and communities—leveraging their expertise and collective willpower to spur energy innovation statewide. Included in that community are not only the utilities present at this meeting, whose work puts them at the vanguard of statewide smart grid deployment and is unprecedented in its cooperative approach but a broad array of committed stakeholders. A sampling of such stakeholders includes private corporations such as NRG Systems and GroSolar, which are headquartered in the state; policymakers committed to energy reform in Vermont; innovative nonprofits, such as the Vermont Technology Council and the Vermont Energy Investment Corporation; and renowned academic institutions, such as the Vermont Law School, Norwich University, and the Vermont State College system.

Longer term, it is hoped that the tools, experience and technology developed by this collaborative venture will form the foundation for an ongoing effort that will showcase Vermont as a model for smart grid deployment and will serve as a national resource to help train the next generation of electricity experts, thus accelerating the nation towards a 21st century energy infrastructure.

For further information, please contact:

Laurie Burnham,
lburnha@sandia.gov,
802-333-3654



Appendix 3: e-Energy Vermont

Meeting Agenda

March 22, 2011, 8 a.m. – 12 p.m.

Severance Conference Room, 225 Kalkin Hall, University of Vermont

8:00 – 8:20 a.m.

- Introductory Remarks/Purpose of Today's Meeting – Domenico Grasso
- The Sandia-Vermont Collaboration – Laurie Burnham
- Introduction to May workshop – John Evans

8:20 – 8:45 a.m.

- Update on Smart-Grid Deployment Activities – Allen Stamp

8:45 – 9:45 a.m.

- Discussion: utilities' needs and concerns

[Break]

10:00 – 11:15 a.m.

Presentation of Research Possibilities:

- *Smart Grid: Architecture, Security and Control*
 - Juan Torres, Manager, Energy and Security Systems, Sandia
 - Paul Hines, Assistant Professor of Engineering, UVM
- *The Smart Grid: a Model of Complexity*
 - Rush Robinett, Senior Manager, Energy and Security Systems, Sandia
 - Maggie Eppstein, Associate Professor of Computer Science, UVM
- *Critical infrastructure protection*
 - Philip Susmann, President, Norwich University Applied Research Institutes
- *Understanding the Demand Side: Human – Decision Making and the Smart Grid*
 - John Wagner, Senior Manager, Sandia
 - Steven Higgins, Professor of Psychiatry, UVM
- *The Vermont Law School's Smart Grid Project*
 - Michael Dworkin, director, Institute for Energy and the Environment, Vermont Law School
 - Kevin Jones, smart grid project lead
- *Energy Innovation through Smart Policy*
 - Nancy Brune, Member of the Technical Staff, Sandia
 - Chris Koliba, Associate Professor in the Community Development and Applied Economics Department, UVM

11:15 a.m. – 12:15 p.m.

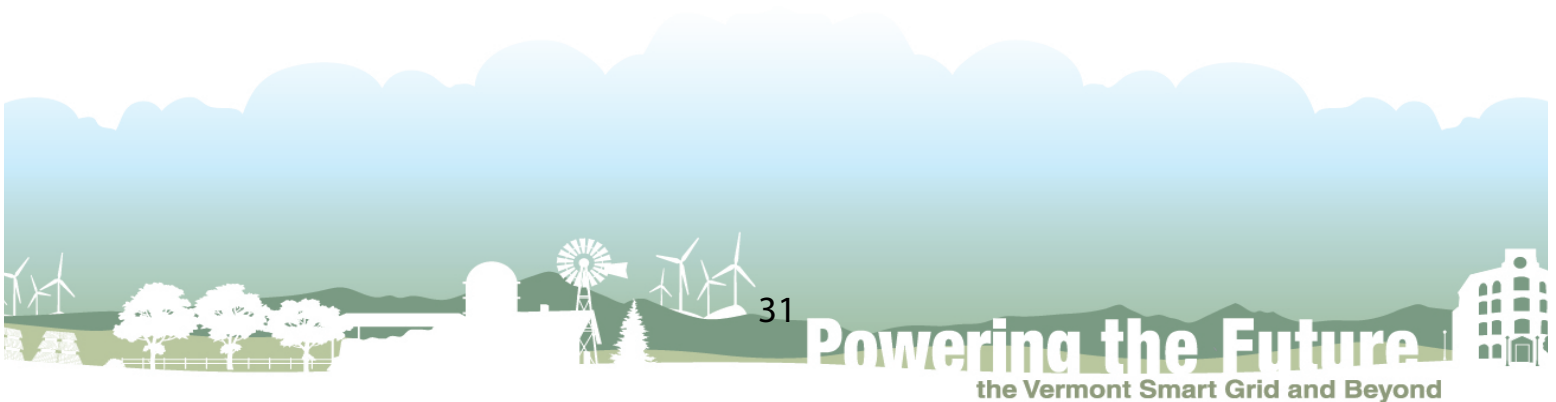
Discussion and Wrap-Up—Bob Hwang

Short Courses, collaborative opportunities, channels of communication, team building etc.

- Cybersecurity Assessment: a Methodology Class: Bryan Richardson and Bob Pollock
- Smart Grid Primer: Juan Torres



- Integrating Renewables into the Grid: Charles Hanley
- Future of PV: Charles Hanley
- Smart Grid Governance Networks: John Wagner
- Smart Microgrids: Design, Control and Operation: Jason Stamp
- Privacy and the Smart Grid: Michael Dworkin
- Smart Grids: What Regulators Think They Are and Can Be...and Why We Should Care: Michael Dworkin
- Energy Governance: Energy Policy and Governance for Sustainable Societies Reducing Stress on the Rural Grid: Michael Dworkin



Appendix 4: e-Energy Vermont Meeting Summary

March 22, 2011

List of Participants

Allen Stamp, Vermont Electric Power Company

Brian Otley, Green Mountain Power

Mary Morris, Green Mountain Power

Jeff Monder, Central Vermont Public Service

Amanda Beraldi, Central Vermont Public Service

Tom Buckley, Burlington Electric Department

Amee Green, Stowe Electric Department

Mary Morris, Green Mountain Power

Jacek Szmrej, Vermont Electric Cooperative

Bill Powell, Washington Electric Cooperative

Shawn Enterline, Vermont Energy Investment Corporation

Ethan Goldman, Vermont Energy Investment Corporation

George Twigg, Vermont Energy Investment Corporation

David Mullet, Group of Municipal Electric Utilities

Hans Mertens, Vermont Department of Public Service

David Scott, RW Beck

Philip Susmann, Norwich University

Stephen Fitzhugh, Norwich University

Gary Kessler, Gary Kessler Associates

Michael Dworkin, Vermont Law School

Kevin Jones, Vermont Law School

Dan Smith, Vermont State Colleges

UVM

Domenico Grasso, Vice President for

Research and Dean of the Graduate College

John Evans, Senior Advisor to the President

Dan Harvey, Chief of Staff, Office of the VP/Research

Jeff Marshall, School of Engineering

Maggie Eppstein, Computer Science Department

Chris Koliba, Community Development and Applied Economics Department

Stephen Higgins, Psychiatry Department

Paul Hines, School of Engineering

Diann Gaalema, Psychiatry Department

Sandia

Bob Hwang, Deputy to the Vice President

Rush Robinett, Senior Manager

Hal Morgan, Senior Manager

Juan Torres, Manager

John Wagner, Manager

Nancy Brune, Technical Staff

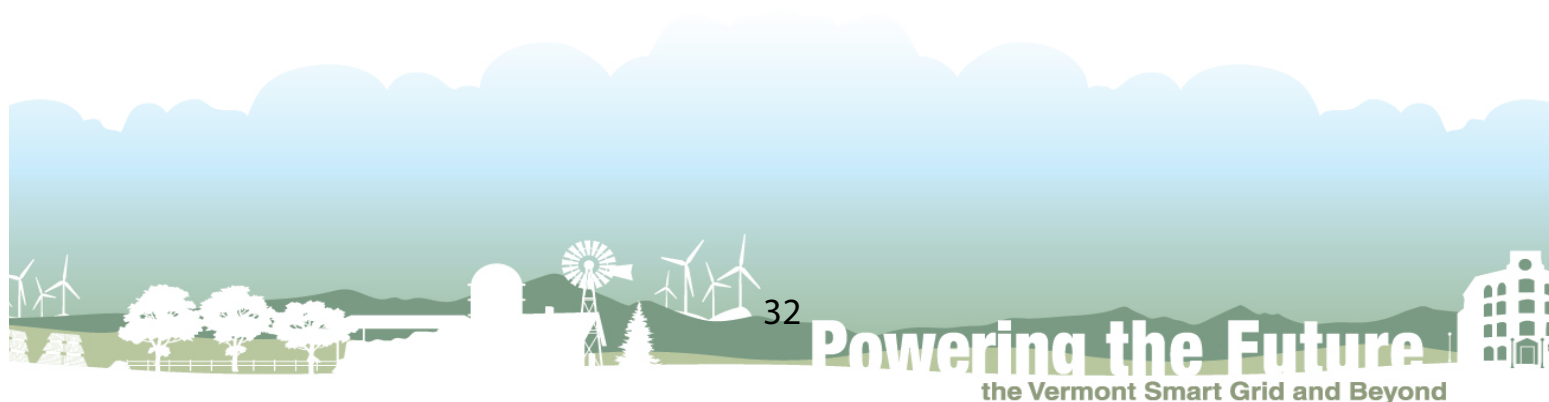
Jim Kamm, Technical Staff

Bob Pollock, Technical Staff

Laurie Burnham, Consultant

Purpose of the Meeting

To identify areas of common interest/expertise related to smart grid deployment that can help address the smart-grid challenges faced by Vermont's collective group of small utilities whose resources are thin and already stretched.



Overview of the Smart Grid Implementation Grant

Allen Stamp provided an update of the work being done in accordance with the Smart Grid Implementation Grant. The e-Energy Vermont team² began meeting in March 2009; the grant was awarded and signed in April 2010; it runs through April 2013.

The purpose of the Smart Grid Implementation Grant is to help put in place a smart-grid base infrastructure, that is, meters and other systems, to enable Vermont customers to interface with smart grid technologies.

Much of the work amounts to a retrofit, with a lot of fiber being laid statewide, but the grant focuses on three core areas.

- Advanced metering infrastructure
- Electric distribution systems
- Customer systems

Advanced metering infrastructure will be deployed according to following schedule:

- Early 2011 – Advanced metering infrastructure selection in progress; also web presentation
- Mid 2011 – Deployment of intermediate networks commences
- Late 2011 – Deployment of advanced metering infrastructure commences

The Smart Grid Implementation Grant team is highly collaborative, including 19 electric utilities as well as the Vermont Energy Efficiency Corporation, the Vermont Department of Public Service and Norwich University. By working together, the group has benefitted from

- improved communication with (and buy-in of) regulators,
- the benefits of scale and common procurements,
- a set of common requirements, and
- a unified mission to make Vermont a smart-grid enabled state.

e-Energy Vermont has the following administrative framework:

- Program Manager: Allen Stamp
- Senior Project Manager: Dave Scott, a consultant with R.W. Beck
- Steering Committee: monitors progress and keeps the team on track

Communications Working Group: creates a “voice” to reflect statewide effort.

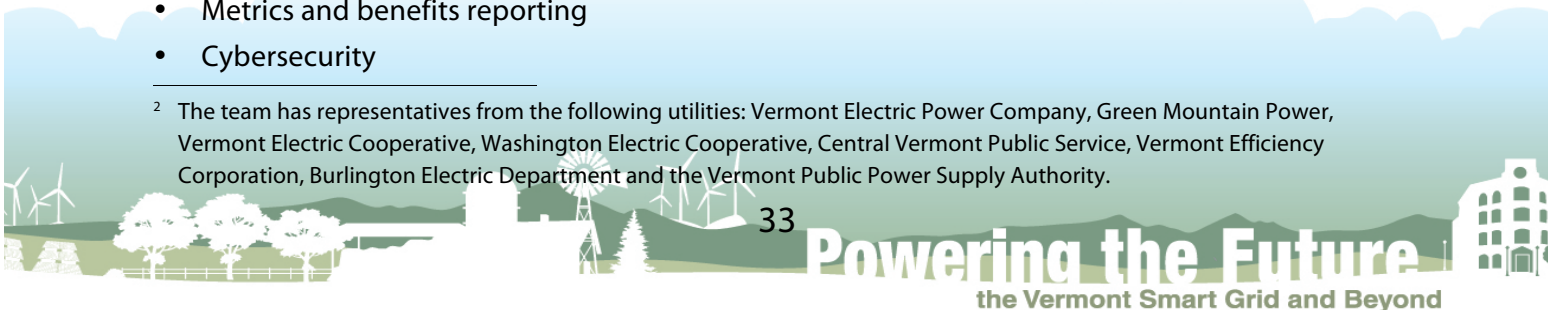
Rates Working Group

Vermont Electric Power Company serves as the central data repository.

The team has developed project plans in the following four areas.

- Project evaluation
- Metrics and benefits reporting
- Cybersecurity

² The team has representatives from the following utilities: Vermont Electric Power Company, Green Mountain Power, Vermont Electric Cooperative, Washington Electric Cooperative, Central Vermont Public Service, Vermont Efficiency Corporation, Burlington Electric Department and the Vermont Public Power Supply Authority.



- Behavioral assessment
Three studies related to consumer behavior are already underway.
 - An analysis of the human/screen interface, a collaboration between Burlington Electric Department and Paul Hines of UVM.
 - A study of rates, an Efficiency Vermont and Vermont Electric Cooperative project.
 - A study of rates and pricing conducted by Central Vermont Public Service.

Nancy Brune—Wants to do case studies to determine which aspects of the Vermont smart grid deployment can be exported to other utilities and to other state policymakers.

Discussion

Three challenges were presented to the audience.

1. How can the assembled group work together to enrich and accelerate the e-Energy Vermont grant?
2. How can we build on the e-Energy activity to serve both Vermont and also the rest of the nation better?
3. What deliverables might the e-Energy team have that the group could help with?

Representatives from the utilities identified the following areas of need and made various comments pertaining to the challenges they face in those areas:

Cybersecurity and Risk

Understanding the cybersecurity of end-user components is vitally important, especially given the aggressive schedule for smart meter deployment.

Vermont's utilities need to understand risks better, as well as standards, and to mitigate risks within a contextual framework.

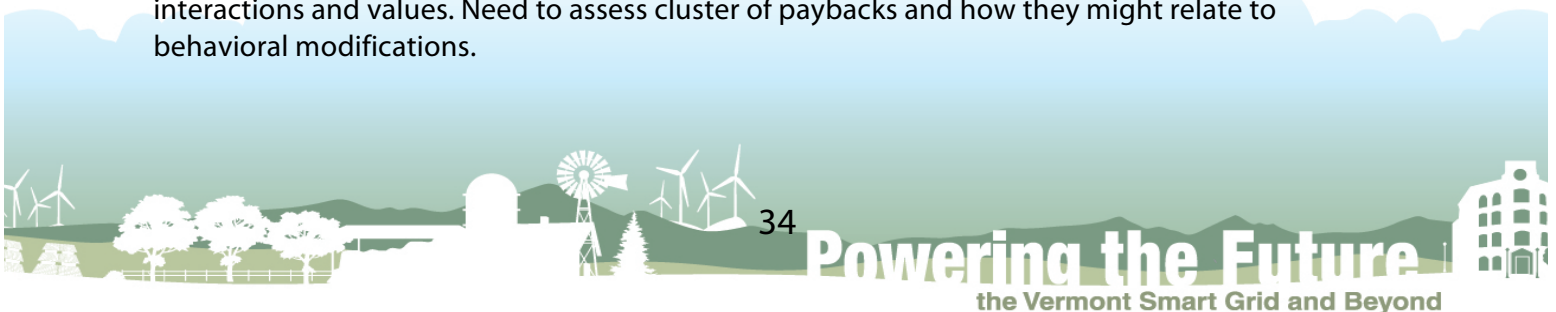
National Institute of Standards and Technology standards are hard to understand as are the risk management processes related to North American Electric Reliability Corporation Critical Infrastructure Protection. One option might be to create an example of implementation of risk management processes applied to everyday operations.

Overall, cybersecurity is an area that lends itself to information sharing and the collective use of resources.

Consumer Interactions/Education/Behavior

The utilities have learned a lot from their work on the efficiency side but smart grid is new territory. They don't know, for example, how consumers are going to react to privacy issues or to the potential health impact of smart meters. It would be enormously helpful to be able to pre-empt consumer reaction.

Consumers need to understand smart grid. Specifically, they need to know that it is not a solution looking for a problem. Need to focus on the customer side of the meter, including customer interactions and values. Need to assess cluster of paybacks and how they might relate to behavioral modifications.



It is imperative for the utilities to address the growing technological expectations of consumers. e-Energy Vermont has a communications group but the group needs help. Even external research and/or analysis would help Vermont meet its smart-grid challenges; how, for example, are consumers responding elsewhere in the U.S. to smart meters?

Central Vermont Public Service is working on customer education; their research shows that most consumers have never heard of smart grid. They are also working with Paul Hines on a behavioral study and will make the data from that available.

In addition, Federal Energy Regulatory Commission Order 745 has the potential to change behavior; smart grid is not about rates yet...very useful to understand these ahead of time.

Microgrids

The utilities need to better understand the implications of microgrids in terms of grid load. The utilities need to think proactively about how to respond to load shedding and what impact a drop in consumption will have on their operations.

Informatics

This is the time to put together an informational baseline. How do you manage the data that drive operations? What do you use them for? The number of smart meters being deployed is not nearly as significant as capturing a set of lessons learned and also a set of success metrics. As part of this process, one can establish codes of conduct for proprietary information that can then be codified and analyzed. This represents a huge opportunity to use data for state planning. Customer usage data that is now available monthly could be disseminated much more frequently.

An opportunity also exists to build business intelligence; Business intelligence = management and mining of big data sets.

Smart is not a technology but an opportunity. Need to take quantities of data and process the data to better understand new systems and how to serve customers. Need that skill set.

Consumer interaction baseline needs to be started right away. Should also start looking at data on meters and cancer. All would agree there is a clear and immediate need to do that.

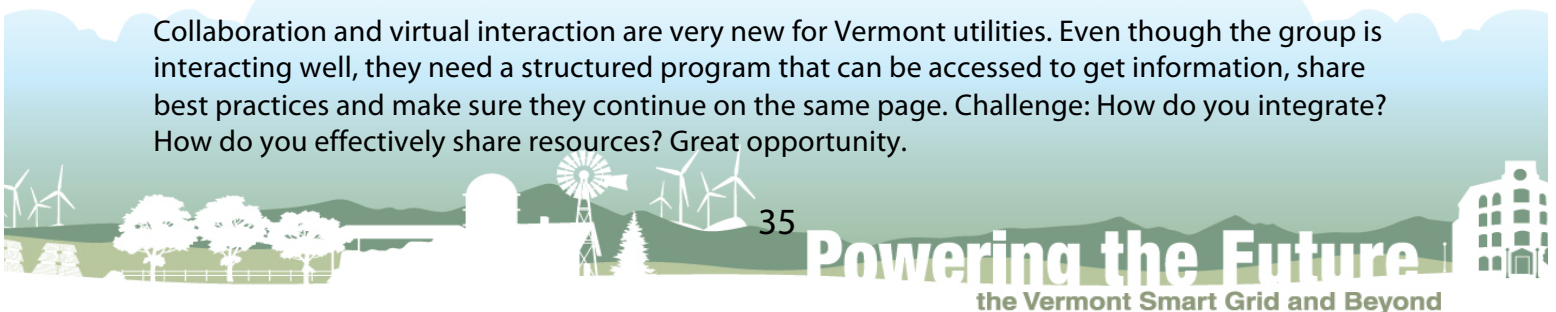
Complex Systems

The Vermont smart grid project is cross-cutting; what are the emergent properties of this complex system? What are the key interactions and how do they affect stability? A key role for Sandia could be to help the utilities identify and address the emergent properties of a complex system.

Economics

The utilities need help understanding the benefits to be accrued from investing in efficiency strategies. Need replicable results so they can use the smart grid as a tool for meeting fuel reduction goals. UVM could help develop models but getting access to the data, while not necessarily off limits, could be a privacy issue.

Collaboration and virtual interaction are very new for Vermont utilities. Even though the group is interacting well, they need a structured program that can be accessed to get information, share best practices and make sure they continue on the same page. Challenge: How do you integrate? How do you effectively share resources? Great opportunity.



Workforce Development and Safety

Field safety in a smart grid world is really important. Can modeling play a role here? Also safety issues related to automation are new.

Could there be an opportunity to develop a simulation program to look at outages? Although utilities help each other when there is an outage, the coordination is not optimal. Gets very complex.

Policy and Regulatory Issues

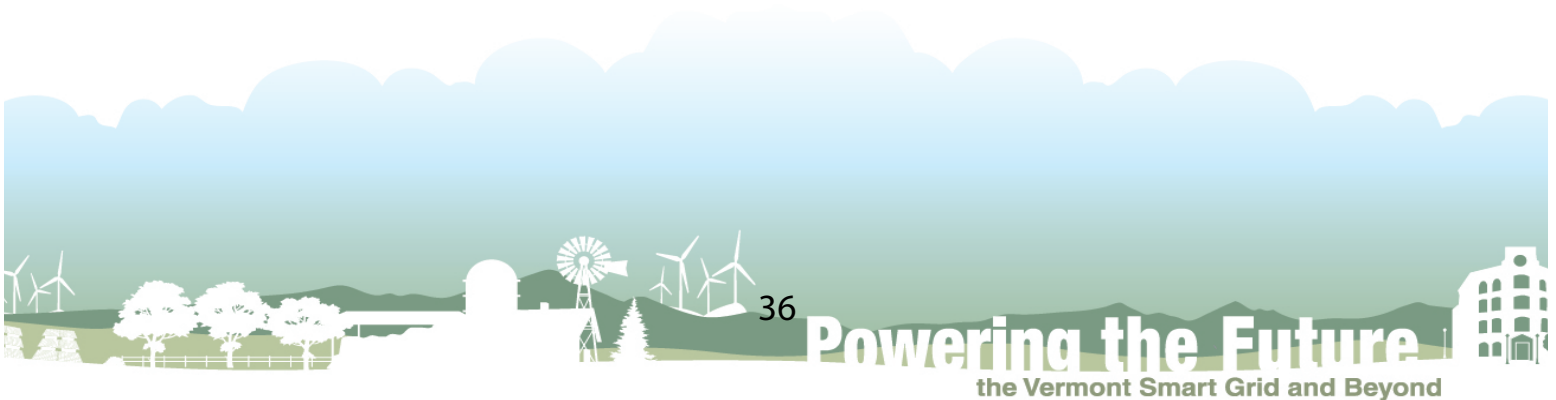
Need to create a coordinated message to send to the Public Service Board when regulatory approval is needed.

Vermont Law School is developing a model privacy policy and also looking broadly at smart grid implementation. They consider signals that affect behavior to be a high-value area.

Applications

Lots of exciting ideas exist at the conceptual level but the theoretical needs to be morphed into an implementable solution in a reasonable time frame.

We are a bunch of small utilities with limited resources and already stretched.



Appendix 5: The Vermont Smart Grid Partnership Stakeholder Conference

Powering the Future: The Vermont Smart Grid and Beyond

Welcome Letter

Dear Conference Participants,

Welcome to *Powering the Future: the Vermont Smart Grid and Beyond*, a conference co-hosted by the University of Vermont and Sandia National Laboratories, with a central objective: to bring together representatives from government, industry and academia to advance Vermont as a national leader in energy innovation and smart grid deployment.

Vermont has made exceptional strides in these areas. With support from the Department of Energy, the state's utilities are laying the backbone for the nation's first statewide smart grid. Before that, Vermont created Efficiency Vermont—the nation's first efficiency utility—to decrease the economic, social and environmental costs of energy consumption statewide. In addition, Vermont's private-sector companies are developing cutting-edge renewable and other energy technologies, and Vermont's federal, state and local governments continue to support and enact policies to further a more energy-independent future. Finally, Vermont's institutions of higher education are conducting innovative research to inform future smart grid investments and also working to develop next generation leaders equipped with the technology, communications, policy, and management skills needed for our 21st century energy future. We are proud of these efforts and proud to provide a forum for highlighting Vermont's advances in energy sustainability.

Each of you was asked to participate in today's invitation-only event because of your accomplishments and leadership in the energy sector, your knowledge of Vermont and your ability to think broadly about energy issues. With your collective help, we hope to achieve the following by the end of this two-day conference:

- A more complete understanding of Vermont's competitive advantages in developing, testing and exporting best-practices for smart-grid deployment and energy optimization;
- A prospectus on the growing collaboration between Vermont and Sandia National Laboratories to further smart grid implementation, promote workforce development and support innovation in the energy sector;
- A collective and multidisciplinary vision for moving forward, one that transcends technology to include policy, workforce development, security, consumer needs and energy management.

Overall, we aim to engage in open dialogue, share our ideas and experiences, voice our concerns and forge new ties. By coming together in this way, we believe we can craft a better and more sustainable future not only for Vermont but also for the rest of the country.

Thank you for your participation.

John Evans, *Special Advisor to the President of the University of Vermont*

Mary Powell, *President and CEO of Green Mountain Power*

Marjorie Tatro, *Director of Energy Technologies and System Solutions at Sandia National Laboratories*



Appendix 6: The Vermont Smart Grid Partnership Stakeholder Conference

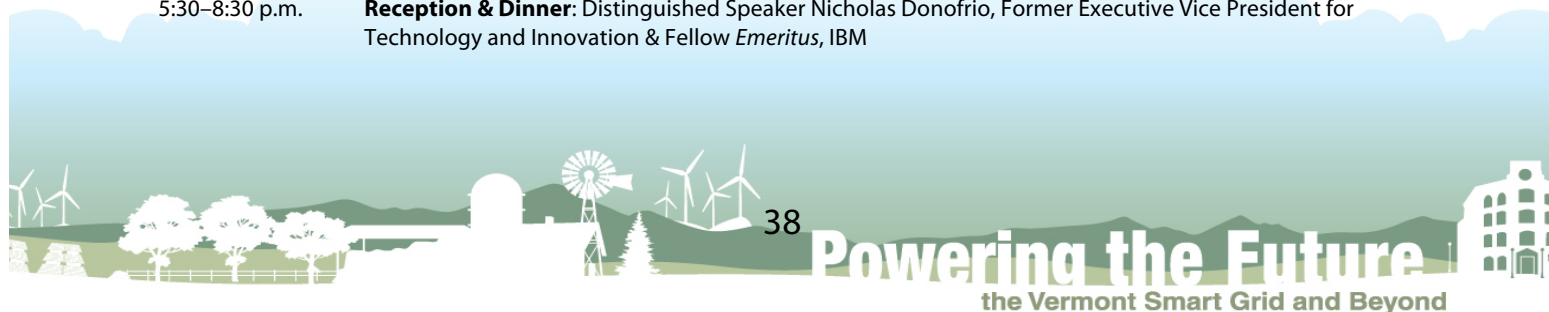
Powering the Future: The Vermont Smart Grid and Beyond

Meeting Agenda

May 17–18, 2011

DAY 1: Tuesday, May 17

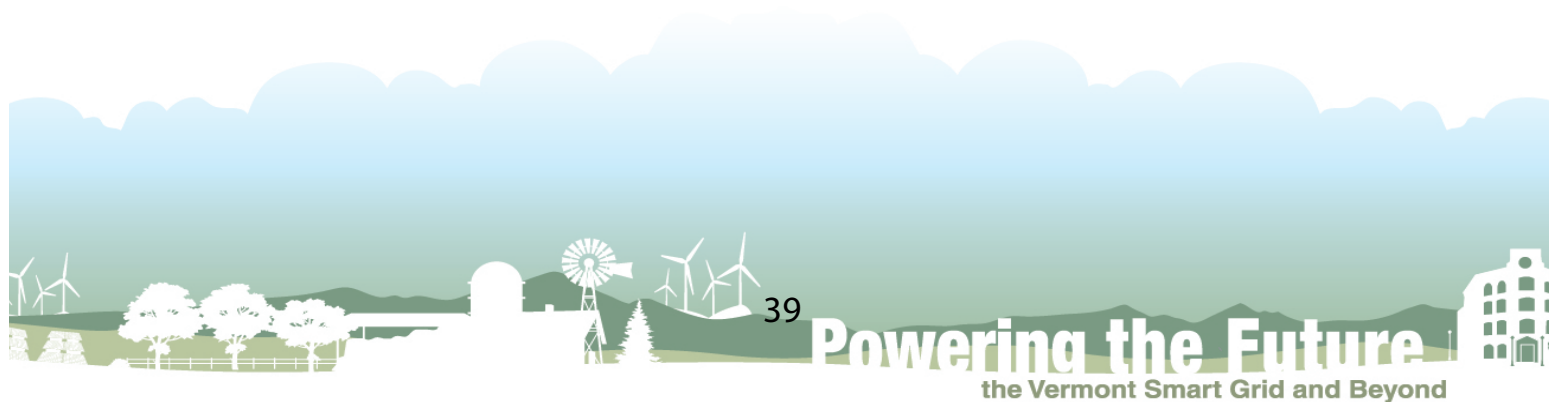
- 8:00–9:00 a.m. Conference registration; continental breakfast
- 9:00–9:10 a.m. **Welcome**
Introductions: Domenico Grasso, Vice President for Research, University of Vermont
- Daniel Mark Fogel, President, University of Vermont
 - Rick Stulen, Vice President, Sandia National Laboratories
- 9:10–10:15 a.m. **Opening Plenary: The Vermont-Sandia Smart Grid Partnership**
Introductions: John N. Evans, Senior Advisor to the UVM President
- U.S. Senator Bernie Sanders, State of Vermont
 - U.S. Senator Jeff Bingaman, State of New Mexico (*video presentation*)
 - Governor Peter Shumlin, State of Vermont
 - Patricia Hoffman, Assistant Secretary for U.S. Department of Energy Office of Electricity Delivery and Energy Reliability
 - Recognition of 2011 Vermont State Science and Math Fair Students
- 10:30–11:45 a.m. **Plenary Panel on Smart Grid Investments and Opportunity in U.S. and Vermont**
Introductions: Bob Hwang, Deputy to the Vice President, Sandia National Laboratories
- Elizabeth Miller, Commissioner, Vermont Department of Public Service
 - Marjorie Tatro, Director, Energy Security Programs, Sandia National Laboratories
 - Lawrence Miller, Secretary, Vermont Agency of Commerce and Community Development
 - Paul Hines, School of Engineering, University of Vermont
 - Dan Ton, Smart Grid R&D Program Manager, U.S. Department of Energy
- 12:00–1:00 p.m. Lunch
- 1:00–2:00 p.m. **Discussion Panel: Smart Grid—A Win-Win for Consumers & Businesses in Vermont**
Moderator: Juan Torres, Manager, Sandia National Laboratories
- Shawn Enterline, Senior Consultant, Vermont Energy Investment Corporation
 - Janette Bombardier, Senior Location Executive, IBM Essex
 - Karen Glitman, Program Manager, UVM Transportation Research Center
 - Larry Reilly, President & CEO, Central Vermont Public Service
- 2:15–3:30 p.m. **Discussion Panel: Smart Meters and Beyond**
Moderator: Allen Stamp, Program Manager for Vermont e-Energy ARRA Grant, Vermont Transco LLC
- Karen Marshall, Chief of Connect Vermont
 - Chris Dutton, President and CEO, Vermont Electric Power Company
 - Robert Dostis, Leader of Customer Relations & External Affairs, Green Mountain Power
 - Phil Susmann, President, Norwich University Applied Research Institutes
 - Juan Torres, Manager, Sandia National Laboratories
- 3:45–4:30 p.m. **Discussion Panel: Smart Grid & the Policy Landscape**
Moderator: Nancy Brune, Sandia National Laboratories
- Darren Springer, Office of U.S. Senator Bernie Sanders
 - Kevin Jones, Smart Grid Leader, Vermont Law School
 - Chris Koliba, Community Development & Applied Economics, University of Vermont
- 4:30–4:45 p.m. **Day One Concluding Remarks**
- 5:30–8:30 p.m. **Reception & Dinner:** Distinguished Speaker Nicholas Donofrio, Former Executive Vice President for Technology and Innovation & Fellow *Emeritus*, IBM



DAY 2: Wednesday, May 18

- 7:30–8:00 a.m. Continental Breakfast
- 8:00–8:15 a.m. **Welcome**
Domenico Grasso, Vice President for Research, University of Vermont
- 8:15–9:15 a.m. **Keynote Address**
Erfan Ibrahim, Technology Executive for Intelligrid Program, Electric Power Research Institute
- 9:30–10:45 a.m. **Discussion Panel: Complexity and the Smart Grid**
Moderator: Peter Dodds, Director of the UVM Complex Systems Center
- Margaret Eppstein, Department of Computer Science, University of Vermont
 - Rush Robinett III, Senior Manager, Sandia National Laboratories
 - John Wagner, Manager, Sandia National Laboratories
 - Tom Janca, IBM Global Technology Services
 - Brian Tivnan, The MITRE Corporation/Vermont Office
- 11:00–12:00 p.m. **Discussion Panel: Education & Workforce to Power the Future**
Moderator: Mary Powell, President & CEO, Green Mountain Power
- Brian Otley, Green Mountain Power
 - Charles Hanley, Manager, Sandia National Laboratories
 - Jeff Marshall, School of Engineering, University of Vermont
 - Tim Donovan, Chancellor of Vermont State Colleges
- 12:00–1:00 p.m. Lunch; Assignment to Breakout Sessions
- 1:00–2:00 p.m. **Breakout Sessions Part I**
- Consumer Interactions
 - Policy & Governance
 - Energy Management
- 2:00–2:30 p.m. Break
- 2:30–3:30 p.m. **Breakout Sessions Part II**
- Modeling & Informatics
 - Workforce Development
 - Cybersecurity
- 3:45–5:00 p.m. Breakout Reports to Conference Attendees & Wrap-Up

***Hosted by the University of Vermont and Sandia National Laboratories
with support from the U.S. Department of Energy***



Appendix 7: The Vermont Smart Grid Partnership Stakeholder Conference

Powering the Future: The Vermont Smart Grid and Beyond Summary of the Breakout Sessions and Recommendations

Breakout #1. Consumer Interactions

Amanda Beraldi – Central Vermont Public Service (speaker); John Wagner – Sandia (discussion leader); Diann Gaalema – UVM (reporter); Melissa Faletra – UVM (rapporteur)

Context for the Session:

How can the public be educated on the benefits of the smart grid? How can effective incentives be designed to induce consumers to use energy more efficiently? How do consumers respond to social influences, and how can this response be shaped by information?

Amanda Beraldi gave details of what Central Vermont Public Service has learned about their consumers by surveying them. They have three categories of customers: early adopters, cautiously optimistic users, and laggards, with the majority falling in the middle. But Beraldi says more needs to be done to create awareness and instill the desire for the customer to become involved with the smart grid.

Two questions were posed of the breakout group.

Question 1: "What are the educational opportunities for engaging consumers?"

The responses fell into four main groups; formal education outreach, informal education outreach, community outreach, and social media.

Ideas for Formal Education Outreach

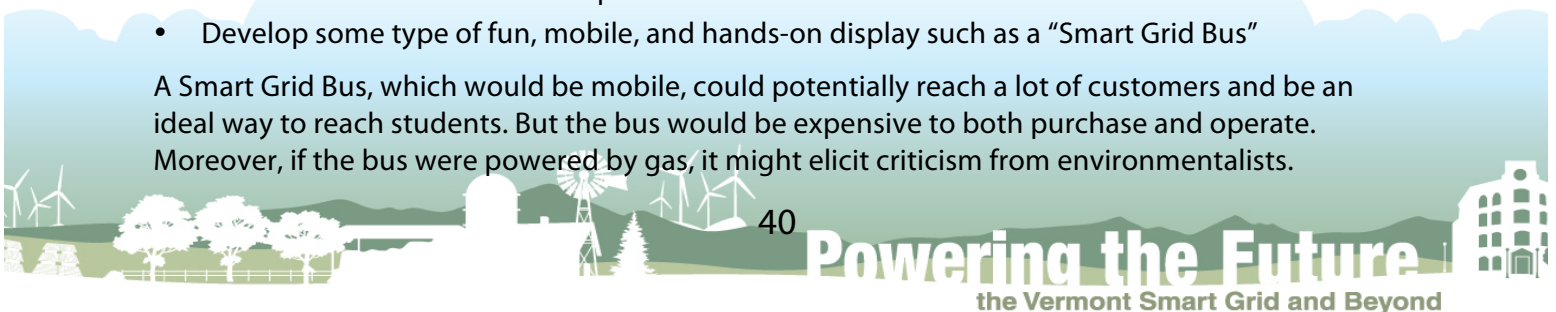
- Bring smart grid presentations, which are easily understandable, to schools, from elementary to college level
- Assign follow-up homework for children to complete with their parents
- Create programs where older students who have been informed about smart grid share their knowledge with younger students

This school-based approach would reach large audiences of parents and students at all income levels but could backfire if the information is not presented in the right way or sounds like propaganda. Also, negative information and commentary could arise and children could misrepresent what they learned to their parents. Another possible complication is that funding would have to be found to train and employ smart grid school presenters

Ideas for Informal Education Outreach

- Introduce public displays in places such as the ECHO Science Center
- Create "Smart Grid Stations" at public libraries
- Develop some type of fun, mobile, and hands-on display such as a "Smart Grid Bus"

A Smart Grid Bus, which would be mobile, could potentially reach a lot of customers and be an ideal way to reach students. But the bus would be expensive to both purchase and operate. Moreover, if the bus were powered by gas, it might elicit criticism from environmentalists.



Ideas for Community Outreach

- Have local government officials reach out to special interests
- Provide information at town meeting day
- Implement bottom-up involvement by appointing local community leaders to serve as smart grid spokespersons
- Begin social networking within communities
- Involve 4H youth, e.g., to sponsor a year of Smart Grid educational activities
- Plan energy conferences in towns, allowing anyone interested to attend
- Turn extension offices with smart meters into demo sites for the community

These ideas would tap into grass-roots support and could have a snowball effect once one community signs on to smart meters. But attendance at meetings might be unpredictable, response times may be slow and contrarians could take over the meetings, spreading fear.

Ideas for Media

- Establish a strong web presence for smart grid, e.g., Facebook, utilities' websites, etc.
- Leverage social networks
- Reach out to, and train, the media about smart grid
- Take advantage of entertainment: create an active game as an educational tool
- Create smart grid applications for cell phones/music players
- Create competitions between businesses in terms of lower electric bills
- Educate through the media: television shows, plays, etc.

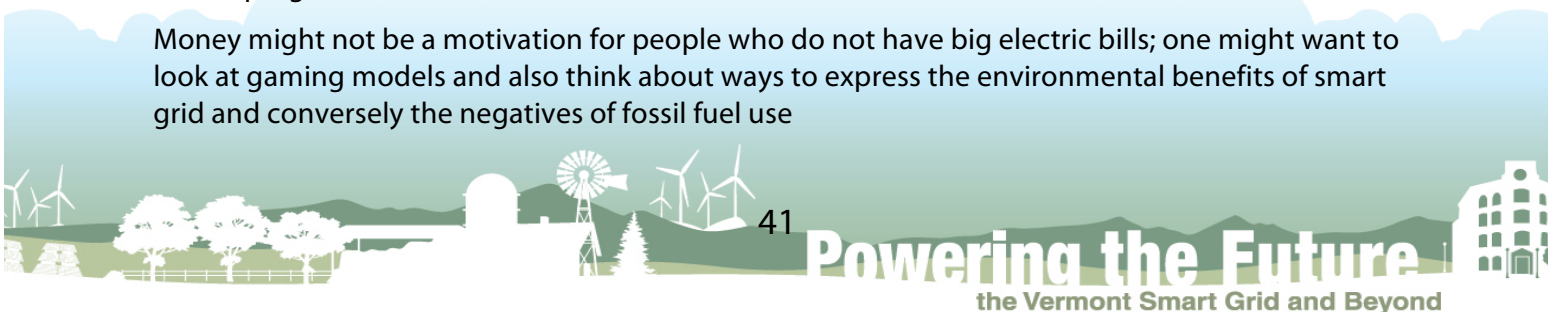
Any of the above ideas has the potential to target high-energy users, is fast and efficient, capable of rapid dissemination and requires relatively few resources. But a significant percentage of Vermonters lacks access to the Internet, to a cell phone and/to broadband; lower-income Vermonters may not even have computers; and the demographics in Vermont skew to the elderly, so this approach could be seen as just benefiting a subset of high-energy, wealthier users. Also the downside of social media is that it can spread fear and make it can hard to distinguish misinformation from valid findings.

Other Ideas

- Include information in utility bill when consumers are thinking about their electric usage.
- Reach out to special interest groups
- Create opportunities for companies and small businesses to learn about smart grid

Question 2: "What will motivate consumers to use smart grid technology to their own and society's benefit? In other words, what incentives will be effective in inducing consumers to use energy more efficiently? Are there lessons learned from recycling, smoking cessation, or other similar programs?"

Money might not be a motivation for people who do not have big electric bills; one might want to look at gaming models and also think about ways to express the environmental benefits of smart grid and conversely the negatives of fossil fuel use



Other thoughts:

- Vermont has interesting models of communication such as Efficiency Vermont, with its hands-on, community-focused approach.
- Building trust is very important; customers need to know that smart grid is not just a marketing campaign.
- Educate journalists about smart grid; perhaps a journalistic voice could be found that does for smart grid what Michael Pollan did for food networks.

Breakout #2. Policy & Governance

Kevin Jones – Vermont Law School (Speaker); Nancy Brune – Sandia (Discussion Leader); Chris Koliba – UVM (Reporter); Francesca Minervini - UVM (Rapporteur)

Context for the session:

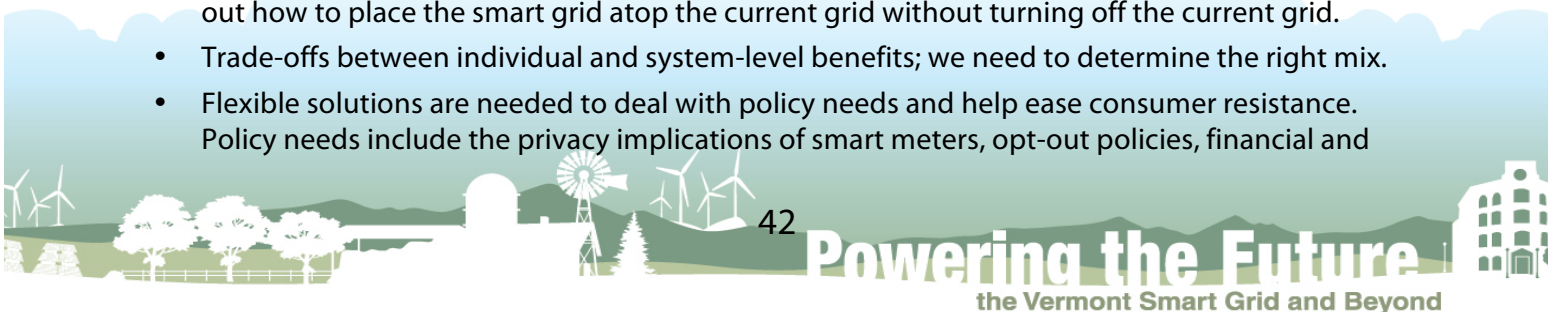
What government policies will best aid smart grid development? How should policies deal with issues of privacy and possible health concerns of some consumers?

Question 1. “What are the strengths of the current system [in Vermont]?”

Vermont has a pre-existing policy group, which has helped heighten interest and educate the public about the smart grid. It was noted that Vermont’s values encompass problem-solving skills and stewardship and that Vermont “wears a very green hat” which helps develop this “platform.” One predominate strength is the success of Vermont’s utilities in working with state regulators. Because channels of communication exist, people can set aside formal roles and talk to each other. A high-level government official, for example, can directly contact anyone in the workforce and get a straight answer to any question related to the smart grid. The result is a very open atmosphere that facilitates discussion. In addition, the e-Energy Vermont Communications Working Group meets every other Friday to share information and plan communications related to smart grid. In addition, telecom and the Vermont utilities are collaborating on a communications infrastructure.

Question 2. “What are the weaknesses or limitations of the current system? What are the future challenges to full smart grid deployment?”

- Traditional roles or lines of responsibility between organizations need to change. But there is still much we do not know about the challenges associated with new consumer roles.
- Vermont’s fragmented education systems are limited in terms of information, dissemination, funding, and resources. A K–12 curriculum must be created *de novo* to educate students. In addition, facts regarding the smart grid, including costs and possible health concerns, need to be organized and disseminated.
- Economy-of-scale in Vermont: Vermont is small, with limited access to financial and human capital and cannot, for example, undertake the development of standards.
- A new policy framework must be built for the smart grid, while still using the existing policy framework for the current grid. One cannot take down one policy framework without having the other already up; meanwhile the lights need to be on at all times—so we need to figure out how to place the smart grid atop the current grid without turning off the current grid.
- Trade-offs between individual and system-level benefits; we need to determine the right mix.
- Flexible solutions are needed to deal with policy needs and help ease consumer resistance. Policy needs include the privacy implications of smart meters, opt-out policies, financial and



operational problems/discrepancies, rates and incentives. In addition, it is unclear at what levels these policies should be set: by the utilities? the state? the federal government?

- Funding the next level of investments after the federal American Recovery and Reinvestment Act money runs out; another round of significant investments is needed but the source of that money remains unclear.
- Determining responsibility. Who is responsible for providing smart grid applications: utilities? Efficiency Vermont? Third-party suppliers? Also, once the network is in place, who makes sure there is infrastructure to support it?
- Managing expectations, including both real and perceived expectations. One must articulate the “real” benefits of the smart grid and not over-promise. It is also important to consider how vulnerable the overall enterprise is to failure or at least to perceptions of failure.
- Framing the “problems” that smart grid addresses including cost, carbon, and reliability.

Question 3. “What opportunities can we leverage? What federal/state policies can help leverage those opportunities?”

- A real commitment to STEM education is needed at the federal and state levels including the necessary resources.
- Encourage consumers to shift away from using less electricity to using less *energy*—promoting the idea of load shifting.
- Develop federal-level opt-out regulations, which would lie outside of the state’s hands and allow for more uniformity.
- Develop and “lock in” a strong relationship between Sandia National Laboratories and Vermont to enable Vermont leadership in smart grid deployment.
- Align smart grid planning with the DPS’s 20 year energy plan, the Public Service Board’s SPEED plan and the voluntary SPEED goals, including RPS.

Other questions, which were not addressed but were presented, include:

- How can the government ensure the public benefits from the smart grid?
- What federal/state policies are needed to ensure we achieve the optimum environmental benefits from the smart grid?
- Are additional federal or state privacy protections necessary to protect consumer data?
- Beyond the installation of meters and the associated automated infrastructure, what is the role of the utility versus third party suppliers in providing smart grid services?

Breakout #3. Energy Management

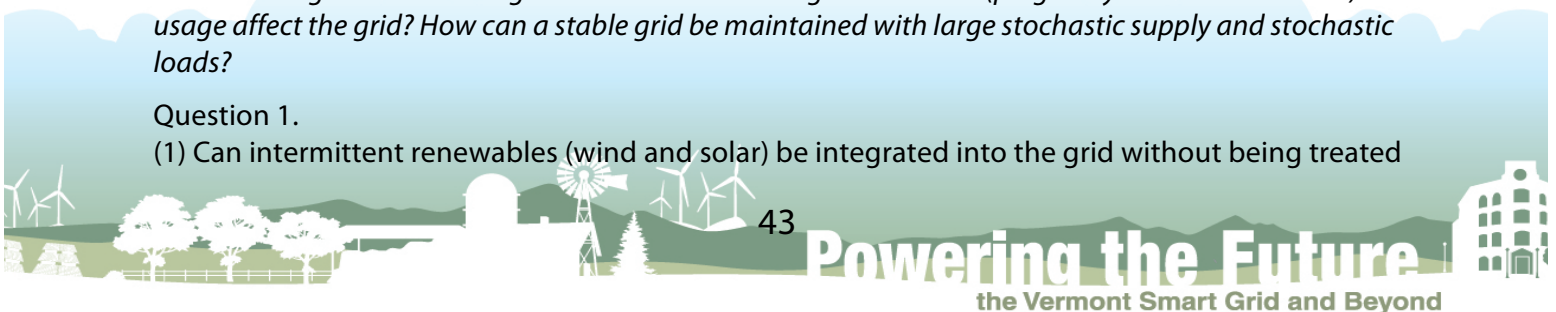
Juan Torres – Sandia (speaker); Paul Hines – UVM (discussion leader); Allen Stamp – Vermont Electric Power Company (reporter); Eduardo Cotilla-Sanchez – UVM (rapporteur)

Context for the Session:

How can intermittent renewables (wind, solar, etc.) be integrated into the grid in large proportions, without being treated as a negative load? How will large-scale PHEV (plug-in hybrid electric vehicle) usage affect the grid? How can a stable grid be maintained with large stochastic supply and stochastic loads?

Question 1.

(1) Can intermittent renewables (wind and solar) be integrated into the grid without being treated



as negative loads? (2) How will the introduction of PHEVs affect the grid? (3) How can the resilience of the grid be maintained while incorporating these stochastic components?

Juan Torres described two energy management projects that embody the quote: "If you can't measure it, you can't manage it."

1. Micro-grids within military installations. The military needs to understand how energy ties into its critical missions but they are not sure about the amount of energy actually used. So, measurement is essential to determine inefficiencies, critical loads and resource allocation. What would you power first and what are the priorities? Sandia is just starting to look at smart meters, heat profile of buildings, etc.
2. The Hawaii Clean Energy Initiative is a partnership between the state of Hawaii and the U.S. Department of Energy to implement an aggressive portfolio of 70% RPS in Hawaii by 2030. Currently, 90% of Hawaii's electricity is generated from diesel. Moving to such aggressive renewables goals means electrification of transportation and taking advantage of Hawaii's solar and wind resources. Because the bulk of Hawaii's wind resources are on Maui, the state needs undersea cables to interconnect the islands, making energy management key.

Question 2. What about the integration of intermittent renewables in Vermont?

A: There are several ongoing wind farm projects in Vermont, including a large one (63 MW) that is under construction.

Q: How is Vermont Electric Power Company dealing with that wind penetration? How is that renewable capacity impacting a peak load of around 1100 MW?

A: In New Mexico, the wind farms are a significant proportion of the generation profile, especially during nighttime. All new wind turbines can vary the pitch to manage wind surplus, at least the large ones, but often times, utilities have trouble with stability and they need to ramp up gas turbines. The ramp-up speed is quick but the plants are designed to come up and stay up and are therefore; therefore becoming more and more expensive to utilize.

A: An important item to clarify is whether we are looking at wind penetration from the point of view of the transmission or the distribution system.

For instance, within the transmission system, ISO New England can support from 20% to 25% wind penetration. The problem is what to do with that wind when it is not needed. On the distribution grid, the injection of wind has the potential to help but also to overload.

A: If we focus on the distribution system, what are the potential solutions to deal with those bidirectional flows?

A: From the perspective of Green Mountain Power (GMP), net metering has to be included in the equation. Net metering projects went from 2% to 4% in Vermont. For instance, when the overflow that comes from wind is not used, it is directed upstream to the Vermont Electric Power Company.

Q: Can we keep adding small generators (small turbines, rooftops, etc.?)

A: Much of that power will likely be used in the neighborhood; the real issue therefore is very large solar or wind farms. One key challenge involving power electronics at that scale is VAR control.



A: In Italy they experienced those challenges when they tried to connect a 7 GW farm. They now know they need to study more carefully the impact these new farms might have on their grid.

A: Another great issue with the integration of renewables, and one that we are already experiencing in Vermont, is that neighbors complain about noise, the way turbines look, etc.

Q: When we talk about obtaining data and metering large solar/wind farms, what is the appropriate data resolution? No study has been done on the benefits of 1 second data.

A: One reason we can't answer the question is that we don't have much data from the utilities to validate against and create standards.

A: We certainly need some consensus, depending on the application. Even before having any standards, producing case studies would be helpful.

Q: What about considering the micro collection of weather data to get a better sense of the intermittency of solar and wind?

A: This is certainly done *a priori* with a local weather analysis to identify the most adequate sites for wind farms. But the sites should be continuously monitored after the installation is in place.

Q: Is residential wind implementation a good idea?

A: In VT, the location of these turbines is not trivial and do not depend solely on wind conditions.

A: Certainly, there are a variety of studies associated with the local effects of wind turbines. For instance, they need to be profiled in compliance with radar when in proximity of military bases.

A: Another engineering problem that is associated with high penetration is the need to update the feeders to handle the new generation profiles.

Also the new generation-load profiles directly impacts energy management practices. The aggregated load profile looks like a Gaussian curve but if one separates the data from commercial and residential loads, two differentiated peaks emerge. Because these two peaks do not perfectly overlap, they create problems for residential rooftops. If treated as negative loads, the installations would create negative data points in the middle of the day, resulting in larger energy flows that need to be managed and rerouted to distant sinks.

A: PHEVs could be considered small generating/storage plants. Even though we can integrate them into the grid during the day to help alleviate the aforementioned unusual load profile, many cars would be at work, which doesn't solve the problem; we need to study carefully where to put the charging stations.

Q: What if a car battery is depleted while at work? That would be inconvenient for customers.

A: The charge/discharge algorithms would take that into account and the car should be fully charged by the end of the day.

A: But battery life could be affected so I think customer incentives are needed.

Other comments:

- Vermont has an E911 program for wind data and is only one of two states (the other is Rhode Island) to have such a comprehensive program.

- It would be useful to consider the tie between solar and street lightning when looking at energy management within a city.

Breakout #4. Modeling & Informatics

Rush Robinett III – Sandia (Speaker); Jeff Marshall – UVM (discussion leader);
Margaret Eppstein – UVM (reporter); Brad Lanute – UVM (rapporteur)

Context for the Session:

The smart grid is an extensive complex system with consumer input in both load and supply. How can this system be modeled? What questions might models, even simplified ones, be expected to answer? How can data from smart meters best be used? Can smart meter data be used to improve predictive models?

Rush Robinett III opened the breakout session with a detailed discussion of how adoption of smart grid technology, (including an advanced metering infrastructure) and increases in distributed generation will change the way in which loads are modeled and tracked.

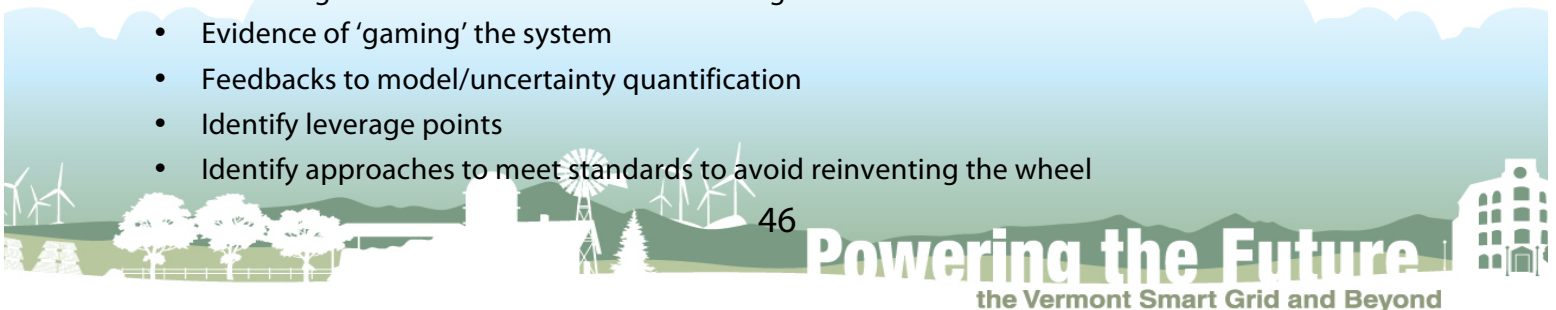
Question 1: What are the objectives, in the context of smart grid technology, to be met by modeling and informatics?

Objectives to be met by modeling:

- Demand-response feedbacks
- Impacts demand
- Reliability
- Optimization of load/online energy management
- Sensitivity analysis to inputs (e.g., demographics/climate change)
- Electromagnetic system dynamic; physically meaningful and significant output
- Understanding how cascading failures propagate
- Tests robustness of model
- Real-time support for operations
- Prediction for new design analysis
- Anticipates 'gaming' of the system
- Scenario planning
- Informs rate design
- Calibration/validation (are the models good enough to be useful?)
- Training

Objectives to be met by informatics

- Understanding contributors to peak load
- Evaluation of tariffs
- Knowledge to inform filtered decision making
- Evidence of 'gaming' the system
- Feedbacks to model/uncertainty quantification
- Identify leverage points
- Identify approaches to meet standards to avoid reinventing the wheel



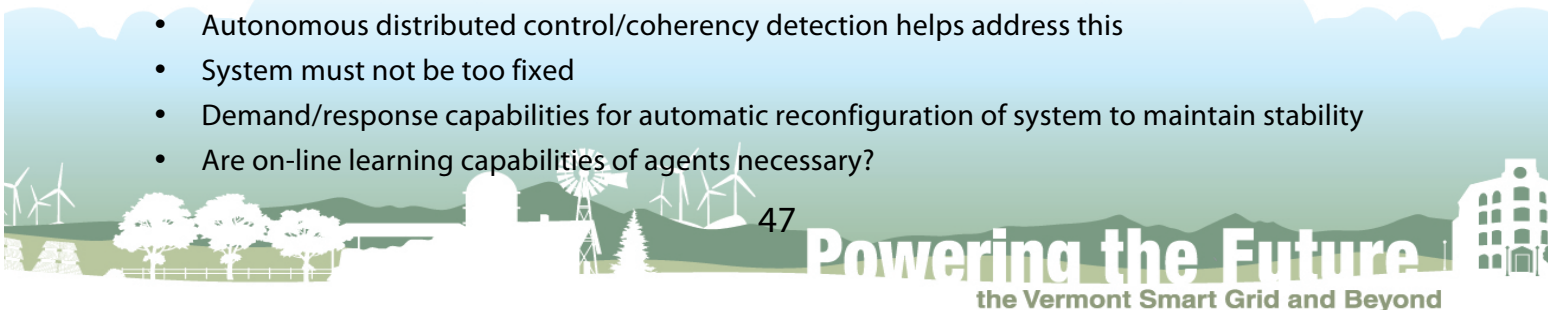
- Predict to excess power production
- Coherency measures to detect imminent failures
- Feedback/assessment of communication effectiveness (e.g., changes in home energy use in response to incentives, etc.)
- Reduced-order modeling (which dimensions and data points are really necessary?)
- Emergency prediction
- Contextual intelligence (finding relevant data for various applications)
- Recognizing efficiency opportunities
- Maps/visualization of spatially-explicit data
- Quantifying achieved benefit from adopted innovation
- Measurement and verification of consumer incentives
- Pattern recognition (e.g., has peak behavior changed?)
- Analyze diffusion of behavioral changes

Question 2: What fundamental advances in modeling are needed to meet the above objectives?

- Better AC models of cascading failures; fundamental physics (validation)/transient analysis
- Better models of human decision making, including social and media influences—for prediction as well as for designing, influencing and informing policy
- Modeling policymakers' decision heuristics
- Integrated modeling platforms (linking models)
- Higher visibility, use, and acceptance of models by the smart grid community
- User-friendly models and modeling tools that lay-people can make and use
- Open source models (or accessible software such as Excel)
- Embedded uncertainty quantification in model predictions
- Verification and validation (for managing expectations)
- Forensics on failed models
- Link ABMs of humans with physical system models
- Efficient data packet size
- Multiscale modeling
- Sensitivity analysis to nuance
- Better inverse modeling (understanding which inputs caused which behaviors)
- Helping consumers understand the value of smart meter data for modeling
- Access to data for modelers
- Use models to help stakeholders agree on goals up front
- Populating the model (automated data entry from smart meters)

Question 3: How will modeling influence the role of “self-healing” in the smart grid?

- Autonomous distributed control/coherency detection helps address this
- System must not be too fixed
- Demand/response capabilities for automatic reconfiguration of system to maintain stability
- Are on-line learning capabilities of agents necessary?



During the discussion, dichotomy emerged between those interested in modeling physical systems and those interested in modeling consumers and decision-making. Both perspectives are needed as are integrated frameworks to couple both perspectives. A dichotomy also emerged in discussing models intended to inform consumer decision-making and models intended to inform operational decision making at the level of energy generation, transmission, and distribution.

Breakout #5. Workforce Development

Brian Otley – Green Mountain Power (speaker); Laurie Burnham – Sandia (discussion leader); Jeff Frolik – UVM (reporter); Melissa Faletra – UVM (rapporteur)

Context for the Session:

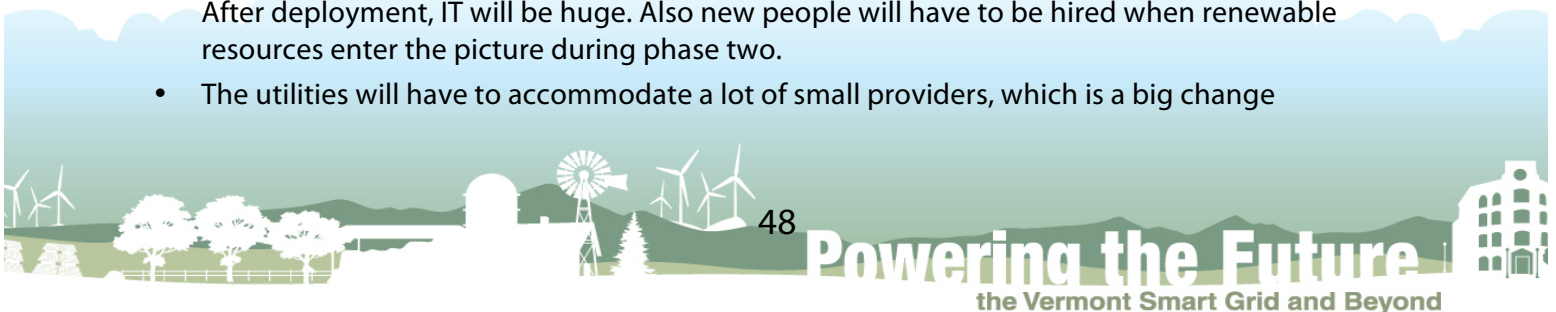
What skills must the smart grid workforce have that are different from the current utilities workforce? How can these skills best be delivered?

Question 1. What new positions, specialties, and skills are needed to deploy and operate the smart grid in Vermont?

- Vermont Electric Cooperative is an example of an organization that is quickly evolving, which is hard for the workers, who need to be flexible, adaptable and have a willingness to change. Vermont is a challenging location, which makes it hard to recruit new talent with phenomenal information technology (IT) skills and strong technical backgrounds from other states. Smart grid has caught employees off guard as the company had not changed much of the past 30 years.
- Smart grid means having to manage and transform a flood of data to help with business intelligence. Vermont Electric Cooperative now has to shift from taking 12 meter readings per year per meter to a huge number of readings. Need to hire people from areas that understand mass data handling, e.g., computational science banking, security sector, health sector etc.
- Both technical and digital skills needed—blending of control center operations with IT
- Also need people with rate design and marketing skills, communication skills and engineers with broad skill sets
- Employees with both IT skills and physical skills are hard to find: IT is primarily language-based while electrical engineering is more physical. Putting an IT person in a physical environment could be dangerous and physics/electrical engineering employees may struggle with IT. While having both physical and IT skills is ideal, it is hard to find this top 1%–2% of people. Therefore one needs a hiring model built around the 50% of people, who may not be experts but at least understand the basics of both the physical and IT sides.

Question 2. Could smart grid deployment in Vermont be delayed by workforce limitations, and if so, what steps should be taken now? What is the balance between short-term and longer-term needs?

- Short term: need to get the equipment out but this is just the first phase of smart grid.
- Long term: Once the equipment is deployed, the right people are needed at the right time to drive infrastructure. Hopefully after the first phase, more broad-based training will emerge. After deployment, IT will be huge. Also new people will have to be hired when renewable resources enter the picture during phase two.
- The utilities will have to accommodate a lot of small providers, which is a big change



- Vermont should consider a “Smart Grid 101” crash course to quickly introduce smart grid skill sets, something like the six-month crash course in Georgia to become a lineman
- Vermont Technical College has a green energy grant to conduct smart grid training for incumbent utility workers and to identify workers at the optimal time for retraining.
- Companies could give a lot of resources and information to their employees

Question 3. Can the existing workforce successfully transition to the smart grid paradigm or will skilled talent be best obtained through workforce replacement?

- A broad range of employees is needed, not just engineers. But it is unreasonable to think that one can totally replace the existing workforce. There is a lot of competition for graduates- it can be challenging to find new talent. In addition, some training is required for everyone for the new system. In addition, the utilities have a relationship with long-time employees and don't want to let them go. The consensus is that employees should have the opportunity to stay in the industry and stay in Vermont but be empowered to develop and change with the industry

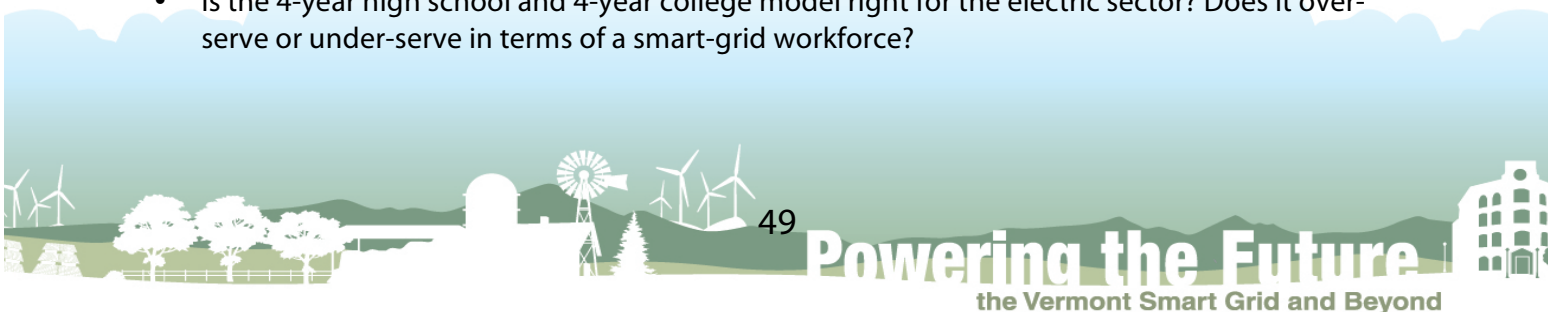
Question 4. Could Vermont be a national leader in workforce development? If so, what will it take? What are the opportunities? What strengths does Vermont bring to the table?

It would be great for Vermont to be part of something bigger. Vermont already leads on the transportation side, with great work being done by UVM's Transportation Research Center. One example from the educational front, the Center hosts a two-week camp for high school students and has produced 300 modules of online curriculum with transportation embedded in it.

But as there will always be power generation in Vermont, there will always be jobs in the electric sector. Important to remember is that people like going to work in places where opportunities within the company are visible and where internal training makes advancement possible.

Other questions, which were presented but not discussed, are listed below:

- How will the smart grid impact employment numbers: will the smart grid mean more or less employees?
- What additional skill sets will emerge, e.g., in terms of renewables integration, substation support, etc.?
- Who should drive workforce education and retraining efforts in the state? And how can those efforts best be delivered?
- How urgent is the need? Is it so great (e.g., a matter of national security) that a new training paradigm is needed? For example, is the military approach of hiring high school graduates and providing vocational and technical training to individuals with no career experience an approach the utilities should consider?
- Should alternative approaches be developed that value, for example, candidates with strong experiential learning needs and abilities over erudition? Can technical and industrial training be strengthened in high school curricula, replacing the traditional sciences for those not seeking an academic or research career?
- Is the 4-year high school and 4-year college model right for the electric sector? Does it over-serve or under-serve in terms of a smart-grid workforce?



Breakout #6. Cybersecurity

Phil Susmann – Norwich (speaker); Ed Talbot – Sandia (discussion leader);
Jeff Monder – Central Vermont Public Service (reporter); Francesca Minervini – UVM (rapporteur)

Context for session:

What threats does the smart grid face, and how are they different than the current grid? How can the smart grid be designed for reliability, in spite of such threats? What is the “end state” that the energy consumer will see 10 years hence? How do you achieve that end state reliably and securely with assured privacy?

Question 1. What will we see and react to? What controls do we need? If attacked, how will the perpetrator be identified and responded to? What are the risks?

Talbot suggested that the most secure systems have limited utility and challenged the group to think about ideas regarding vulnerability. When one thinks about the cybersecurity for the smart grid, for example, consumer privacy must be considered. The conversation then moved to a discussion of what defines an “attack”. Definitions proffered included the following:

- Data exploitation.
- “When an enemy breaches security and comes in.”
- Environmental terrorists, e.g., someone who remotely adjusts another person’s air-conditioning levels without consent.
- Eavesdropping because it can lead to unfair economic advantages.
- Unwelcome/unauthorized use of resources

Question 2. How does one prepare for attacks?

One responder said, “You can never protect against every threat, you will never come up with every possible type of attack.” One also needs to take into account, as stated earlier, that increased security decreases applicability.

The group then discussed *how* you test for a secure system, which means testing for the worst threat possible. One person stated, “It’s like testing software, you don’t test it to find all the bugs, because you never will.” “Ethical hacking” was presented as a way to develop a secure system because one purposefully hacks into one’s own system to identify and fix vulnerabilities.

Different motivations for cyberattacks, which include financial gain, political motivation, data collection and network dominance, were also discussed, as was risk. Elements of risk were identified as supply chain integrity (where did the data come from?), network interconnections, inadequate technology/standards, and more access to previously firewalled systems.

Because the threat is continuous and adaptive, people must constantly work to protect themselves from threats.

The following elements were identified as important to the cybersecurity of the grid:

- Architecture
- Management
- Secure posture
- Vulnerability assessment: Identify your critical assets; you can’t protect everything, so prioritize according to what needs the most protection



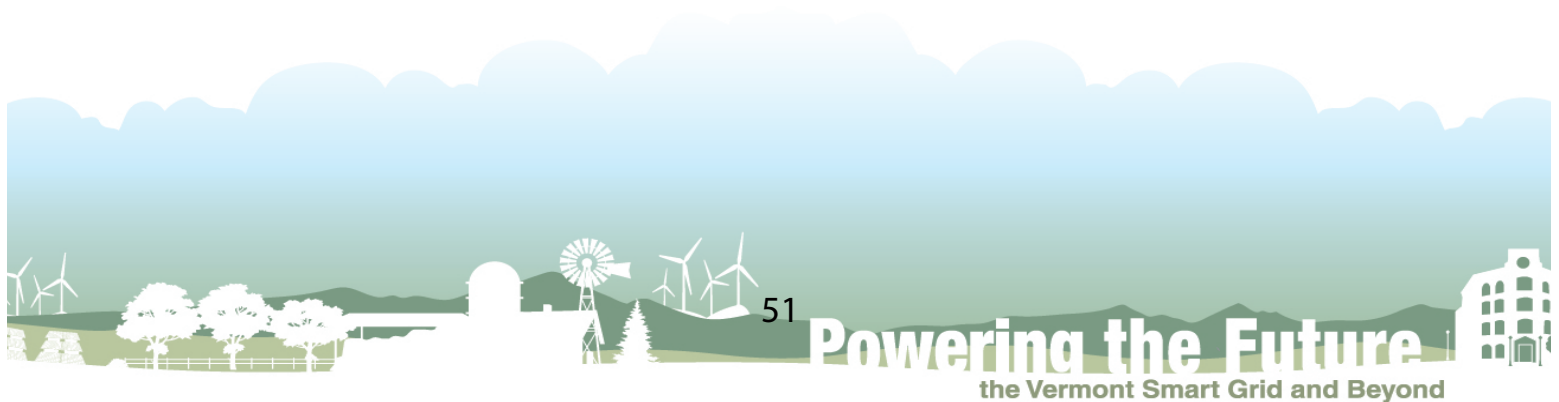
Question 3. How can the smart grid be designed to be reliable, secure, and private? And how do you investigate devices that have been attacked? For example, when person 1 hacks into the back account of person 2, wipes the back account clean, and then makes it look like the crime was committed by person 3, how does one investigate this type of attack and determine the real perpetrator?

Three difference consequence questions were developed for assessing risk:

1. If *confidentiality* is breached, is that a problem?
2. How do you determine the *integrity* of your data? What if someone attacks and modifies a set of data while making the data look untouched, original, and legitimate?
3. How can you ensure the *availability* of your system?

Other questions included:

- Even if you clean the data, how careful do you have to be with anonymized data?
- Can one establish bilateral agreements for third party data?
- Who, besides individual utilities/companies can help track data tamperers? (The FBI, local law enforcement, etc.)



Appendix 8: Smart Grid Technology Courses

Over the summer of 2011, Sandia National Laboratories, the University of Vermont and the Vermont Law School collaborated on a set of three technology short courses designed to meet the needs of Vermont's electric utilities with respect to workforce training around smart grid deployment. Administered by UVM's Continuing Education, and held on the UVM campus, the courses drew capacity crowds. The course descriptions are provided here.

Renewable Energy Integration Course

Date: July 26, 2011

Location: UVM

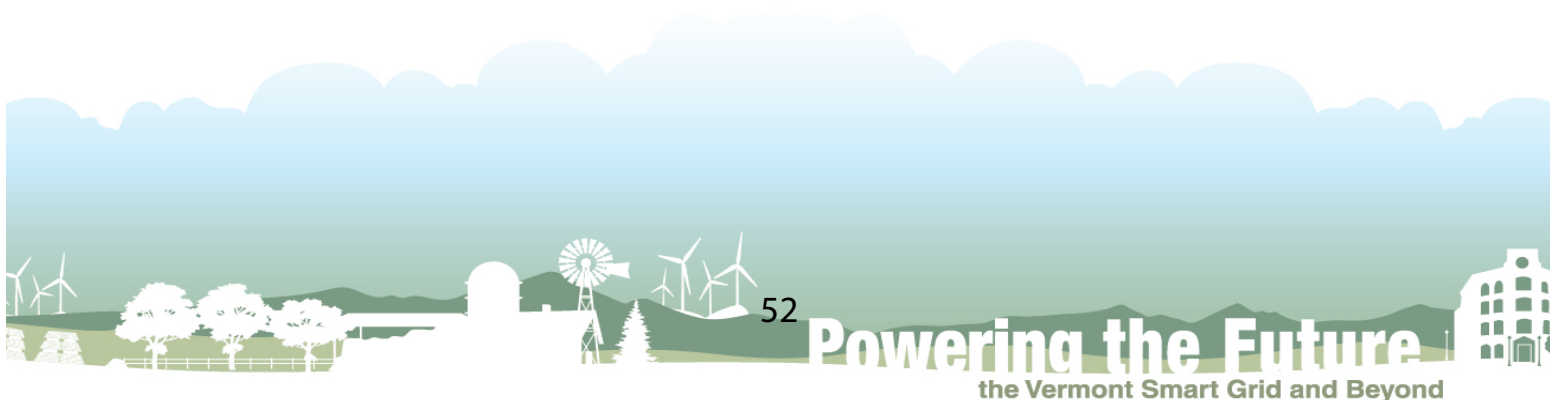
Description: This one-day course will look at the broader energy infrastructure into which renewables will be integrated, the advances in design and components, and the smart technologies that will allow renewables to interface with the larger smart-grid architecture. Fundamental changes are underway that will transform the electric grid from a passive operation to a sophisticated smart system based on two-way communication networks, sensors, smart meters and controllable power devices. This transformation will allow for greater efficiency and reliability and open the grid to significant amounts of electricity from intermittent renewable sources. Other factors driving the growth of renewables are energy security, global climate change and technical advances that have lowered the costs and limitations of renewables in areas ranging from mechanical design and materials usage to data monitoring, power conversion and storage options. Instructor: Joshua Stein, member of Photovoltaics and Grid Integration Department at Sandia National Laboratories, and his Sandia colleagues.

Who should attend: Aimed at representatives from utilities and energy technology companies, graduate students in engineering, computer science, and environmental.

Topics to be covered:

Overview of the U.S. Energy Situation and Renewable Energy Technologies:

- Energy flow trends, implications for greenhouse gas reductions, energy projections for the U.S., data from the Energy Information Agency, limitations of that data. Vermont specific data.
- Latest technological developments in wind, solar power, geothermal, hydropower, fuel cells and energy storage systems, examining the characteristics and challenges to each.
- Challenges and Barriers to Renewable Energy Integration – Current roadblocks to widespread adoption, interconnection of renewable sources of generation, efforts to remove integration barriers, current wind and solar grid integration studies, and future trends. How variable generation (wind and solar) impacts grid operations and planning. Impact on both local distribution system and the operation and control of the bulk power system.
- Solar Energy Case Studies – Review of current research projects aimed at better understanding the output characteristics of solar photovoltaic systems.



Smart Grid Policy: Pathways for Improving the Global Environment

Date: July 27, 2011

Location: UVM

Description: This one-day course will address smart grid benefits that go beyond basic utility business justifications, such as meter reading and outage-management automation, to broader societal goals regarding the improvement of the global environment. Utilizing examples from the Vermont Law School's ongoing case study research that demonstrate various approaches to both reductions in US energy consumption and carbon emissions made possible by the implementation of a smart electric grid and related services. The course will also incorporate the Electric Power Research Institute's (EPRI) work on distribution automation including conservation voltage reduction. This short course will examine the smart grid from an environmental vantage, looking at the legal, regulatory and other policy changes that can best ensure Smart Grid implementation in the US meets the nation's clean energy goals.

Who should attend: Aimed at utilities, regulators, policy makers, investors, technology companies, and consumers who are interested in exploring the pathways for a smart electric grid to improve the global environment. Jointly taught by Kevin Jones and other members of the Smart Grid Research Project Team at the Vermont Law School's Institute for Energy and the Environment, Jeffrey Roark of EPRI and Nancy Brune of Sandia National Laboratories. Continuing Legal Education (CLE) credit may be available for this course.

Topics to be covered:

Overview of the opportunities for environmental improvement, interactive discussion of policy options and choices:

- Increased energy efficiency/demand response
- Distributed generation and electric storage
- Electric vehicle integration
- Distribution automation and optimization

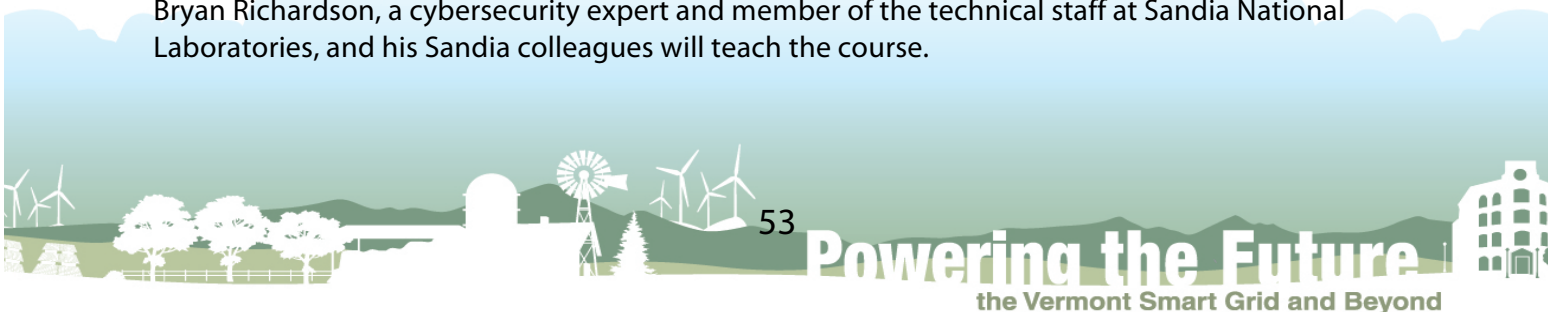
Cybersecurity of the Smart Grid

Date: August 2–3, 2011

Location: UVM

Description: This two-day course is a broad introduction to the cybersecurity of the smart grid, examining the security challenges raised by its two-way communications systems, wireless technologies, distributed sources of electricity and network of sensors and other smart devices, and mitigation strategies to minimize security risk. Most organizations have a limited understanding of the cyber threats they face, vulnerabilities in their systems, and possible consequences of a cyber attack or even the impact of security on their real-time operations. Threats are real and consequences serious. Engage in hands-on training exercises to understand pathways of attack, vulnerabilities, appropriate assessment and security actions in a model control system.

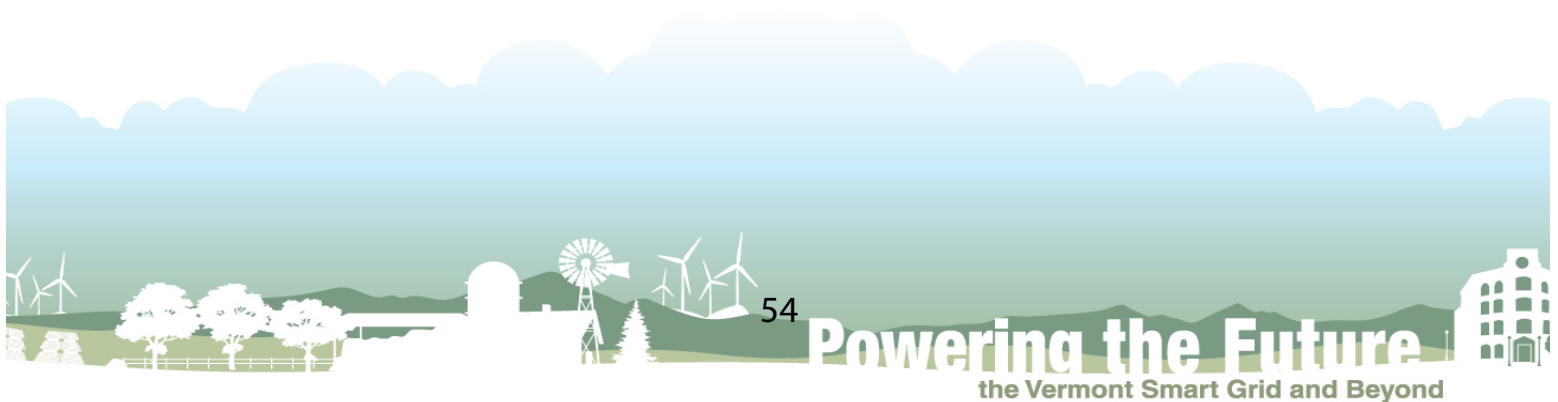
Who should attend: The course is aimed at IT specialists and control room engineers from utilities and energy technology companies, engineering and computer science graduate students. Bryan Richardson, a cybersecurity expert and member of the technical staff at Sandia National Laboratories, and his Sandia colleagues will teach the course.



Topics to be covered:

- The Cyber Threat—Targets, perpetrators, how/why/when attacks may occur.
- Government and Industry Standards/Regulation—Security standards, Federal Energy Regulatory Commission Critical Infrastructure Protection and National Institute of Standards and Technology interoperability standards. Regulations that affect control systems will also be covered.
- Security framework—When implemented together security and policy frameworks can add resilience to the grid.
- Smart Grid Attack Vectors—Specific attacks scenarios involving advanced metering infrastructure and other parts of the smart grid architecture.
- Self-Assessment—Undertaking an appropriate cyber assessment and ensure best security practices.

Note: Because of the hands-on component of this class, class size is limited to 30 students.



Appendix 9: Smart Grid Outreach at the ECHO Lake Aquarium and Science Center in Burlington, Vermont

As part of education and outreach activities supported by the Power Systems Fellowship Program grant, Sandia and the e-Energy Vermont Communications Working Group proposed they help develop a smart grid exhibit for the Vermont public. The following is a rationale for such a smart grid display and is followed by a statement of work submitted by the ECHO Lake Aquarium and Science Center to Sandia, requesting funds to support the display.

Smart Grid Outreach Project at ECHO Lake Aquarium and Science Center

The Smart Grid Outreach Project at ECHO Lake Aquarium and Science Center (ECHO) will further awareness of the significant changes taking place in the nation's electric sector, helping the public understand—through a multimedia exhibit and interactive programs facilitated by student interns—how electricity works, what “smart grid” means, and how the smart grid can contribute to better environmental stewardship, in a venue that is trusted and valued by the public.

Background and Objectives

Sandia National Laboratories, the University of Vermont, the e-Energy Vermont Communications Working Group (including Burlington Electric Department, Central Vermont Public Service, Green Mountain Power, Vermont Electric Cooperative, Vermont Electric Power Company, and Vermont Energy Investment Corporation, as well as the Department of Public Service) and ECHO in Burlington, Vermont, are working together to create a multimedia exhibit and interactive programs for public participation this summer at ECHO.

The exhibit and programs which will be jointly supported by participating utilities and several private companies, have the following **near-term objectives**:

- To introduce the public to the electric grid, including the science of electricity, the concept of peak load, and the basic pattern of electricity generation, distribution and use.
- To introduce the public to the smart grid, an innovative concept of the 21st century based on two-way communication systems that allow for better load management, increased reliability, more distributed sources of electricity and greater consumer participation.
- To engage the public in hands-on activities that will give them familiarity with smart meters and related smart grid technologies.
- To describe the potential environmental benefits of the smart grid, including its ability to accommodate significant amounts of electricity from renewable sources, to incorporate electric vehicles into the grid, to offset the need for additional power plants and to increase the role of individual stewardship in promoting smarter energy use.
- To survey public awareness of—and interest in—the smart grid and to develop prototype techniques for evaluating the impact of public outreach strategies.
- To further opportunities for collaboration (and open additional channels of communication) among Vermont's smart grid stakeholders: utilities, academic and educational organizations, the private sector and government.
- To engage student interns in the development and facilitation of outreach materials. The intent is to engage the students' interest in a smart-grid-related career, further their overall



understanding of power systems, cultivate their public communication skills, and provide role models for other students of all ages.

- To document public responses to outreach materials that in turn will inform further development of the exhibit and related programs and help determine the design and content of future public outreach materials.

The **longer-term objectives** of the exhibit and programs are to:

- Create a sustainable outreach project that leverages the resources of ECHO and other informal educational organizations to communicate to broad public audiences, including schools and communities, about the smart grid.
- Modify the project model for dissemination regionally and nationally, either as a traveling suite of programs and exhibits or in the form of a set of blueprints/how-to guidelines for science centers and museums wishing to engage in similar partnership models.
- Provide the public with ongoing, updated information related to smart-grid deployment in Vermont.
- Optimize public understanding of the changing grid by creating outreach strategies that are nimble and responsive to emerging technologies.
- Collect ongoing data on public responses to smart grid applications such as real time pricing, demand response, the environmental benefits of the smart grid, etc.
- Gain national attention by presenting the project at an annual conference for science-museum curators and educators (e.g., the Association of Science-Technology Centers.)

Statement of Work Provided by the ECHO Lake Aquarium and Science Center

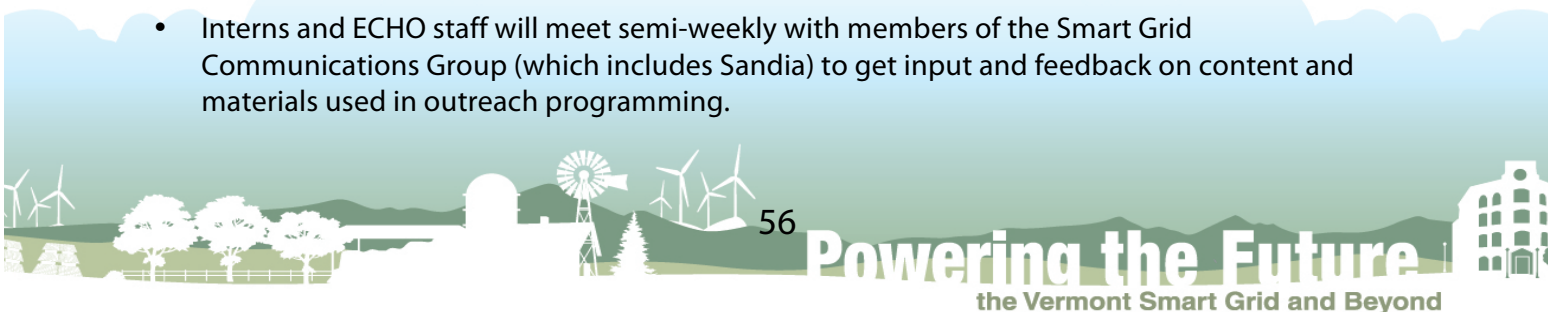
Sandia National Laboratories, the University of Vermont, the e-Energy Vermont Communications Working Group (including Burlington Electric Department, Central Vermont Public Service, Green Mountain Power, Vermont Electric Cooperative, Vermont Electric Power Company, and Vermont Energy Investment Corporation, as well as the Department of Public Service) and ECHO in Burlington, Vermont, are working together to create a multi-media exhibit and interactive programs for public participation this summer at ECHO

This smart grid project will further public understanding of the electric sector, helping visitors see—through a multimedia exhibit and interactive programs facilitated by student interns--how electricity works, what “smart grid” means, and how the smart grid can contribute to better environmental stewardship, in a venue that is trusted and valued by the public.

Sandia will support two student interns for the period of July 11–August 28 to engage in the following activities.

Activities

- Interns will spend 30 hours/week developing and delivering educational outreach programming at ECHO.
- Interns and ECHO staff will meet semi-weekly with members of the Smart Grid Communications Group (which includes Sandia) to get input and feedback on content and materials used in outreach programming.



- Interns will develop materials and deliver programs on ECHO's exhibit floor. As part of this process, they will spend time training as general educators on ECHO's exhibit floor, researching and developing outreach programming, delivering at least one daily program, and documenting their experiences.

Period of performance

Sandia will provide funds to cover the student interns' salary for the period from July 4, 2011 through August 28, 2011.

Support of the project will help achieve the following objectives

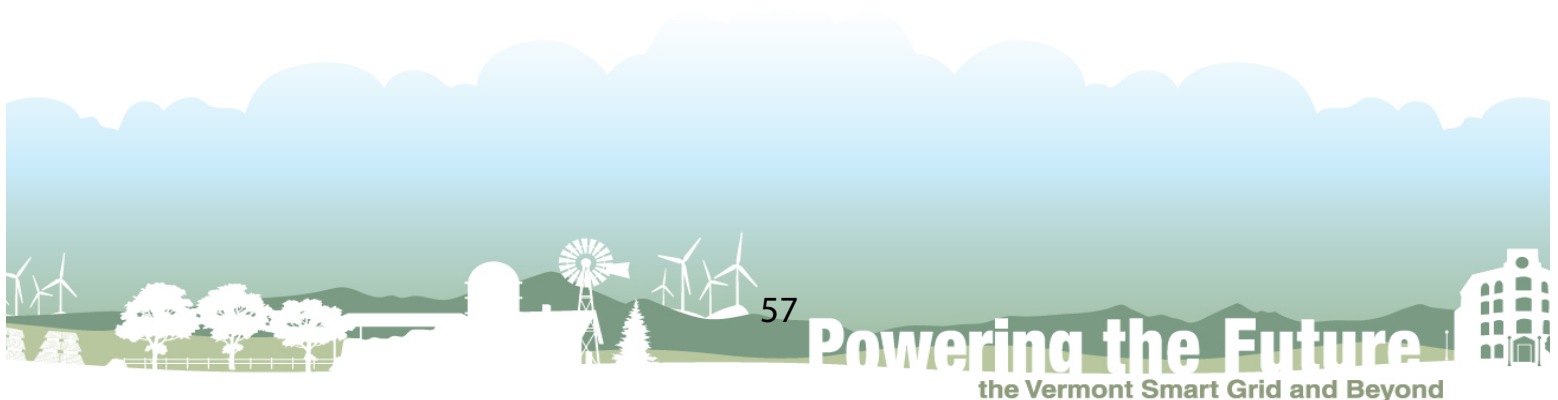
- Engage student interns in the development of smart-grid related materials and promote their interest in smart-grid-related careers, further their overall understanding of power systems, cultivate their public communication skills, and provide role models for other students.
- Enable the interns to work with the public on hands-on activities that will give them familiarity with smart meters and related smart grid technologies.
- Enlist the interns' help in documenting public responses to outreach materials that in turn will inform further development of the exhibit and related programs, help determine the design and content of future public outreach materials and possibly result in a publishable paper.

The project will have the following deliverables

- Display on ECHO's science workbench exhibit that provides an overview to smart grid technology through information panels, artifacts and audiovisual content.
- On-site activities and demonstrations related to three key topic areas, which will be defined with members of the Smart Grid Communications Group and developed into hands-on activities to be delivered daily on ECHO's floor.
- Weekly progress journals written by the interns that document the training program, the development of display materials and interactions with the ECHO visitors.
- Informal report on visitors' general understanding and questions about smart grid technology and response to outreach programming.

Contact Information

- The Principal Investigator on the contract is Molly Loomis, director of education at ECHO.
- The primary contact is Chris Miller, director of finance at ECHO.
- The period of performance is July 11–August 12, 2011.



ECHO Smart Grid Interns



Brianna Baker is a senior at the University of Vermont, majoring in civil engineering (with an environmental focus) and minoring in community and international development. She is also a Vermont scholar, a member of Tau Beta Pi Engineering Honor Society, Chi Epsilon Civil Engineering Honor Society and the National Society of Collegiate Scholars. Last spring and summer she worked on an international engineering development project in Honduras; this past year she co-taught an outdoor leadership development class at UVM. Overall, she is eager to learn more about smart grid technologies and to engage with the public on topics related to energy. Brianna grew up in Barre, Vermont.



Kristofer Sellstrom graduated this May from the University of Vermont, with a Bachelors of Science degree in electrical engineering and a strong interest in the development of the smart grid. Working under the tutelage of Paul Hines, professor of engineering and smart grid expert at the University of Vermont, Kris completed a senior project on the topic of household energy use, creating a visual depiction of electricity flow to various appliances. Kris has also tutored students in topics related to the smart grid, such as wireless communications systems. While at UVM, Kris was active in the Vermont Student Government Association, made the Dean's List in 2010 and was nominated for UVM's Outstanding Leader Award that same year. Kris hails from Jamestown, New York.

Appendix 10: UVM – Sandia Research Exchanges

Sandia Summer Exchange

Students and faculty at the University of Vermont traveled to Sandia during the months of May, June, July and August to engage in a technical exchange related to smart grid and power systems research. The objective was to expose the UVM researchers to the technical capabilities that exist at Sandia and to engage them in meaningful research as a way to expand interest, especially among students, in applying their skills to innovation and technological advancement in the electric power sector.

June

July

August

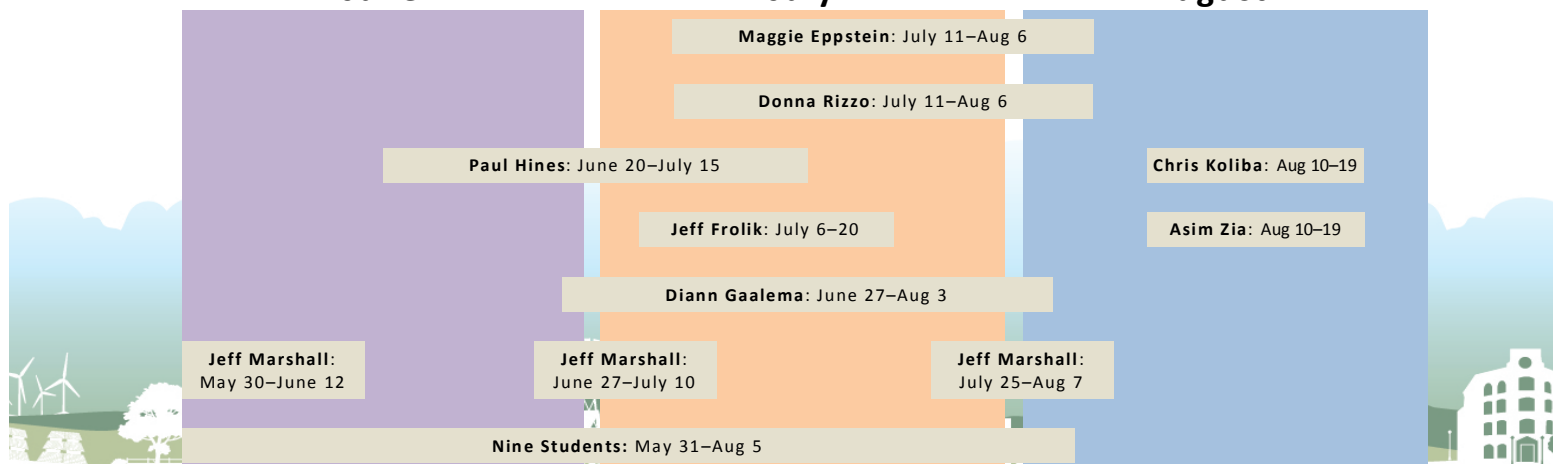
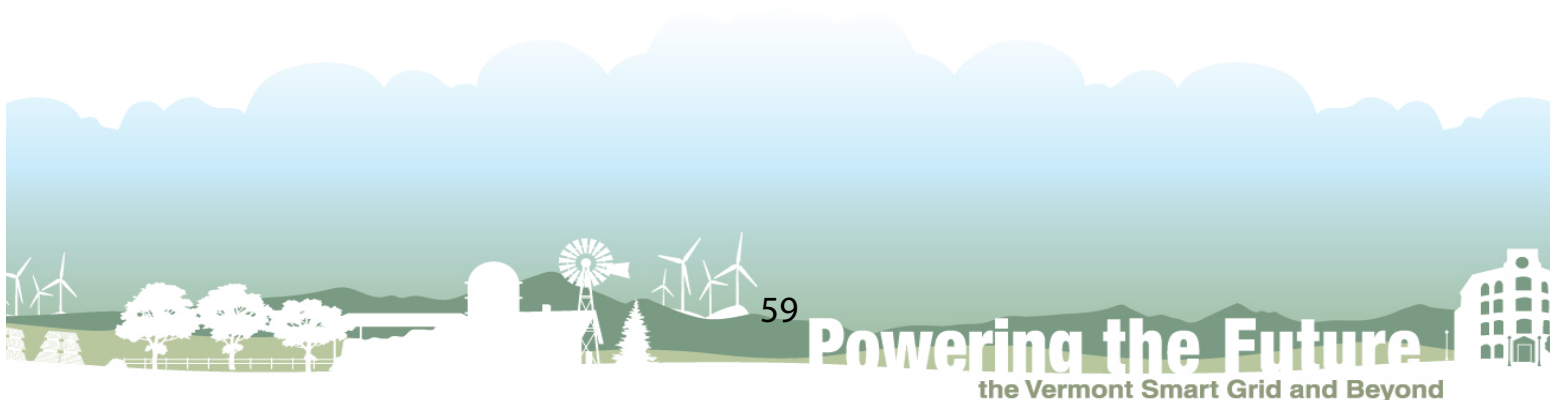


Figure 6. *Schedule for University of Vermont researchers visiting Sandia in 2011.*

UVM Faculty

Eight UVM faculty visited Sandia over the course of the summer, engaging in research in a diversity of areas:

- Dr. Margaret (Maggie) Eppstein, Associate Professor of Computer Science
1-month exchange: complex systems (mid-July to mid-August)
- Dr. Paul Hines, Assistant Professor of Electrical Engineering
1-month exchange: smart grid (mid-June to mid-July)
- Dr. Jeff Marshall, Professor of Mechanical Engineering
1½-months exchange: 1 month smart grid research, ½ month rotating (May 30–June 12, June 27–July 10, July 25–August 7)
- Dr. Chris Koliba, Associate Professor of Community Development & Applied Economics
2-week exchange each: policy, complex systems (middle of August)
- Dr. Asim Zia, Associate Professor of Community Development & Applied Economics
2-week exchange: policy, complex systems (middle of August)
- Dr. Jeff Frolik, Associate Professor of Electrical Engineering
2-week exchange: wireless sensors (August 8–19)
- Dr. Donna Rizzo, Associate Professor of Civil & Environmental Engineering
1-month exchange: optimization, neural nets, complex systems modeling (mid-July to mid-August)
- Dr. Diann Gaalema, Postdoctoral Research Fellow, Psychiatry (working with Steve Higgins)
1-month exchange: behavior (June 27–August 3)



UVM Students

The following nine UVM students, including both undergraduate and graduate students representing several departments, spent 10 weeks at Sandia, working with laboratory research staff:

Brad Lanute (Natural Resources)

Nathan Palmer (Mechanical Engineering)

Chris Palombini (Electrical Engineering)

Chris Parmer (Electrical Engineering)

Francesca Minervini (Mechanical Engineering)

Jiarui David Zhang (Mechanical Engineering)

Andrew Seier (Mechanical Engineering)

Eduardo Cotilla-Sanchez (Electrical Engineering)

Melissa Faletra (Mechanical Engineering)



Figure 7. Student interns from the University of Vermont spent the summer of 2011 at Sandia researching topics related to the smart grid.

Appendix 11: Collaborative Research

Sandia Staff–UVM Faculty/Student Projects

Research Projects

The research undertaken at Sandia by UVM students and faculty focused primarily on electrification of transportation, with the following nine collaborative projects emerging from the summer effort:

Project 1

Title: Electric Grid Communications with High Renewables Penetration

Participants: Students Andrew Seier (Electrical Engineering MS) and Chris Palombini (Electrical Engineering Ph.D.), UVM Professor Jeff Frolik, Sandian Anthony Lentine

Goal: Examine the communications needs required to implement reliable microgrids that have high penetration of renewable generation.

Strategy: A strategy for both wireless and power line communications that leverages probabilistic automata was explored.

Outcomes: A paper has been submitted to the 2012 International Communications Conference for the Selected Area of Communications Smart-Grid session.

Project 2

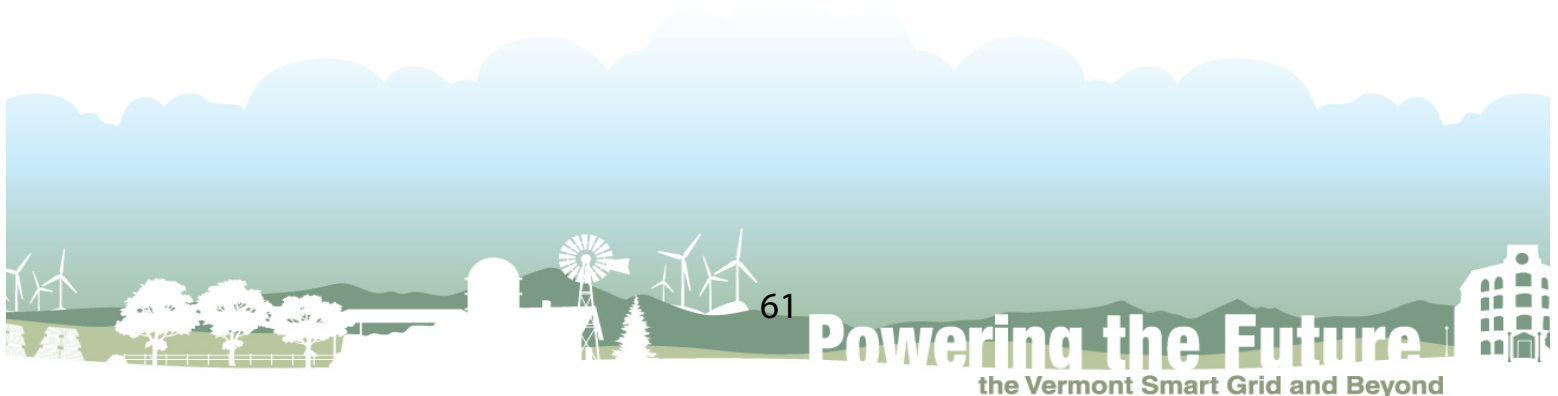
Title: Effects of Clustering on Opinion Propagation on Online Social Networks

Participants: Students Melissa Faletra and Nate Palmer (both Mechanical Engineering undergraduates), UVM Professor Jeff Marshall, with advice from Sandians Michael Bernard and Kiran Lakkaraju

Goal: Formulate a computational model for the role of social media in spreading of opinions in social networks, such as opinions on the smart grid or penetration of PHEVs (plug-in hybrid electric vehicles), and use the model to explore best ways to educate the public about benefits of the smart grid.

Strategy: The group has developed and implemented a code for generation of scale-free networks with variable clustering and numbers of mutual 'friends', which reasonably mimics communications via social media. A simplified decision model has also been implemented, as well as an algorithm for identifying clusters within the network. The work is continuing during the fall semester at UVM, during which we plan to use this model to examine effects of different advertisement and educational strategies.

Outcomes: We plan to write the results as a journal article to be submitted in the late fall.



Project 3

Title: Effects of PHEV Charging on Thermal Degradation of Underground Cables

Participants: Students Francesca Minervini and Jiarui David Zhang (both Mechanical Engineering undergraduates), UVM Professors Jeff Marshall and Paul Hines, with advice by Sandians Abbas Akhil and Jason Stamp

Goal: Understand the effect of PHEV charging on transient heat transfer and resulting thermal degradation of underground cable systems.

Strategy: Using data from a national transportation survey, a computational model has been developed for the effect on the electric load curve of different levels of PHEV penetration and different rates of PHEV charging. A thermal model for transient heat transfer in the soil for different cable configurations has been developed based on the overset grid approach, and the computational model has been implemented and successfully tested. We plan to couple the results of the thermal computations to a model of thermal degradation of the cables to examine how much faster the cables will degrade with PHEV charging and the sensitivity of enhanced degradation to change in shape of the load curve (e.g., which could be achieved by real-time pricing).

Outcomes: We plan to write the results as a journal article to be submitted in the late fall. A proposal to continue work in this area has been submitted to the UVM Transportation Research Center for support under a US DoT grant, with matching support from Green Mountain Power.

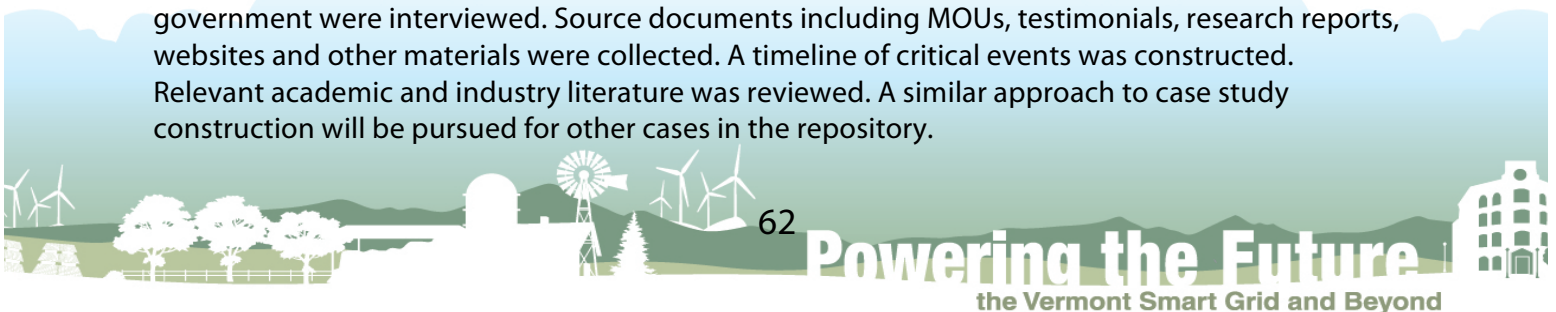
Project 4

Title: Implementing a Statewide Smart Meter Infrastructure: What the e-Energy Vermont Collaborative Case Can Tell Us About the Future of Public-Private Partnerships and Regulatory Subsystems in the Smart Grid Era

Participants: UVM faculty Christopher Koliba and Asim Zia; Sandian Nancy Brune; Industry and government officials: Kerrick Johnson, Vermont Electric Power Company; Alan Stamp, Vermont Electric Power Company; Brian Otley, Green Mountain Power; Jeff Monder, Central Vermont Public Service Corporation; Jeannie Elias, Vermont Department of Public Service; George Young, Vermont Public Service Board

Goal: The primary goal of this project is to describe the history of Vermont's efforts to institute a statewide smart meter infrastructure, analyze the factors contributing to the initial success of the initiative, and anticipate the opportunities and challenges facing the next phases of smart grid development. A secondary goal of this project is to lay the foundation for the creation of a repository of smart meter implementation case studies for comparative analysis and the eventual development of complex systems models that integrate institutional dynamics with technological and consumer drivers.

Strategy: Employ a comprehensive case study analysis approach to data analysis and synthesis. To construct the e-Energy Vermont case thirty-five stakeholders from across industry and government were interviewed. Source documents including MOUs, testimonials, research reports, websites and other materials were collected. A timeline of critical events was constructed. Relevant academic and industry literature was reviewed. A similar approach to case study construction will be pursued for other cases in the repository.



Outcomes: The outputs derived from this project include: a policy brief written to the Department of Energy summarizing the key findings drawn from the e-Energy Vermont case study; at least one peer reviewed publication that situates the e-Energy Vermont case within the context of industry and governance trends, opportunities and challenges; a Harvard Business-style teaching case; and at least one joint UVM-Sandia grant proposal designed to support the development of a case study repository.

Project 5

Title: Simulating Consumer Behavioral Change under Alternate Smart Grid Policy Regimes

Participants: UVM faculty Asim Zia and Chris Koliba, Sandian Robert G. Abbott

Goal: The project seeks to understand how policies that are introduced under a smart grid infrastructure will alter consumer energy consumption behavior.

Strategy: Using real-time smart meter data, contingent valuation surveys and information on smart grid policies, a computer simulation model will be developed to track consumer behavioral change in their energy consumption strategies under business-as-usual and alternate smart grid policy regimes.

Outcomes: A grant proposal is being written to seek necessary resources for implementing the pilot phase of the project in 2012-13 through participation of relevant stakeholder groups in computer simulation model development processes.

Project 6

Title: Use of Mechanical Turk to Perform Consumer Choice Surveys for Assessment of PHEV Penetration

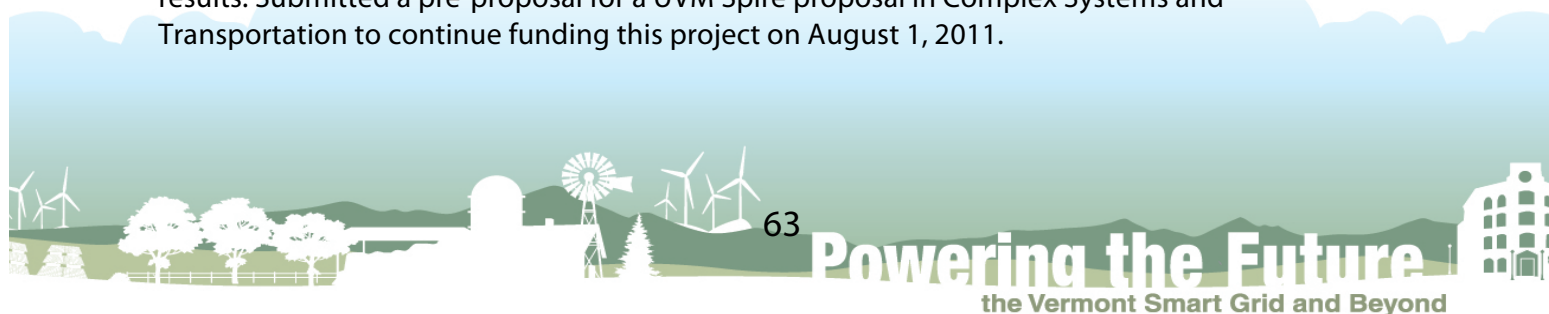
Participants: UVM student Brad Lanute, UVM post-doc Diann Galeema, UVM faculty members Maggie Eppstein and Donna Rizzo, Sandia researchers Kiran Lakkaraju and Christy Warrender.

Goal: To utilize Amazon Mechanical Turk to gather data relating PHEV consumer purchase preferences to consumer demographics.

Strategy: Developed and implemented Amazon Mechanical Turk (MTurk) surveys on PHEV consumer purchase preferences, and leveraged UVM transportation research center grant to fund the surveys. Specific survey activities included:

- a. assessment of demographics of Turkers;
- b. replication of delay, social, and probabilistic discounting studies from the behavioral economics literature for validation of MTurk as a survey platform; and
- c. development of an extensive set of survey questions to inform our agent-based model of PHEV market penetration.

Outcomes: One paper related to analysis of survey results, improved agent-based model for studying market penetration of PHEVs; one paper related to improved PHEV agent-based model results. Submitted a pre-proposal for a UVM Spire proposal in Complex Systems and Transportation to continue funding this project on August 1, 2011.



Project 7

Title: Real-Time Photovoltaic Model Performance Calibration

Participants: UVM student A.J. Rossman, UVM faculty Donna Rizzo, Margaret Eppstein and Paul Hines, Sandians Josh Stein and Chris Cameron

Goal: This project will facilitate optimal scheduling of both emergency and preventative maintenance field service calls for commercial photovoltaic (PV) power plants.

Strategy: We're working on optimizing the operations and maintenance of PV power plants using real-time measurements of energy production and climate data in concert with PV system performance models. To achieve this, the project will use Bayesian Kalman filtering approaches for real-time calibration of PV system models for the purposes of (a) more accurately predicting system power output, (b) anticipating and scheduling necessary maintenance, and (c) rapidly identifying component failures requiring repair.

Outcomes: A proposal was developed and submitted to Josh Stein to fund two years of a graduate research fellowship for a UVM Civil & Environmental Engineering Ph.D. student. The project is scheduled to begin in January, 2012.

Project 8

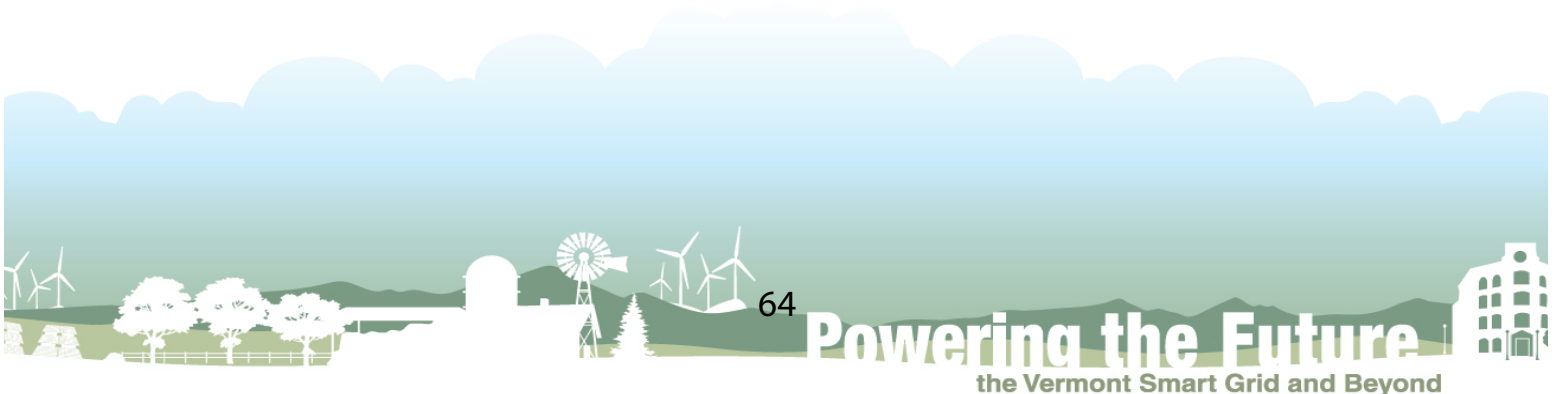
Title: K-way Nonlinear Interactions Leading to Cascading Electric Grid Failures

Participants: UVM faculty Maggie Eppstein and Paul Hines; Sandian Jean-Paul Watson

Goal: The project is focused on identifying types of k-way interactions between components of an electric grid that lead to failure.

Strategy: Identified scale-free relationships for the likelihood of participation of specific branch outages occurring in 2-, 3-, 4-, and 5-way interactions that lead to cascading failures and studied patterns of resting flows on participating branches. Generated sets of 2-way interactions that do not lead to cascading failures but have statistically identical distributions of pair-wise resting flows as 2-way interactions that do cause failures, and searched for topological differences between these two sets. So far, we have found significant differences in (a) shortest paths between branch pairs and (b) maximum branch limits within 1-hop of buses attached to ends of branch pairs that do cause cascading failures and those that don't. Plan to use (a) supervised counter-propagation artificial neural networks and (b) unsupervised self-organizing maps to try to identify non-linear patterns in branch features that help to predict likelihood of participating in 2-way sets that cause cascading failures.

Outcomes: At least one conference paper, one journal article submitted to IEEE Transactions on Power Systems (entitled, "A 'Random Chemistry' Algorithm for Identifying Multiple Contingencies that Initiate Cascading Failure"), and one National Science Foundation proposal will be developed on this work.



Project 9

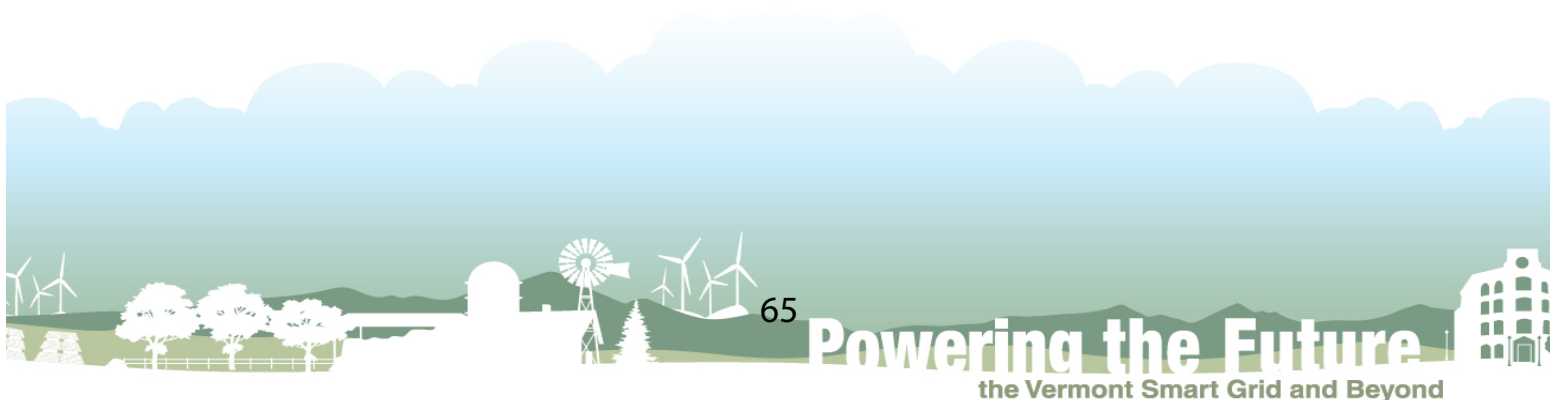
Title: Developing a Dynamic Model of Cascading Failure for High Performance Computing Applications

Participants: UVM faculty Paul Hines; UVM students Eduardo Cotilla-Sanchez and Chris Parmer; Sandian Heidi Thornquist.

Goal: This project is focused on developing methods to simulate the dynamic processes which small disturbances in power systems can result in large blackout, in a way that harnesses High Performance Computing Resources.

Strategy: Despite their infrequency, large blackouts make up a substantial fraction of total reliability losses in the United States. Hurricanes, ice storms and cascading failures cause all of the largest blackouts in the US. Reducing the impact of cascading failures requires, at a minimum, that grid planners and operators have better information about the many ways that cascading failure can occur. This project focuses on the use of high performance computing to provide operators with simulators that can simulate cascading failure in a sufficiently timely manner to produce real-time risk information. To date, the team has identified a number of patterns in the numerical algorithms and data that are required for grid simulation that indicate paths to dramatically decrease simulation time. For example we have found that some less-common linear system solution codes perform dramatically more efficiently than standard algorithms. Going forward we plan to work with Sandia, and industry partners, to apply this simulator to important smart grid problems, such as increasing operator situational awareness.

Outcomes: To date the project has resulted in one accepted conference paper submission entitled, "Developing a Dynamic Model of Cascading Failure for High-Performance Computing using Trilinos." Going forward we expect that this will enable members of the project team to contribute to national efforts to use high-performance computing to improve power system simulation methods.



Distribution

Sandia National Laboratories

1	MS 9001	Rick Stulen, 8000	1	MS 1318	Jim Kamm, 1441
1	MS 0124	Bob Hwang, 8004	1	MS 0127	Nancy Brune, 0249
1	MS0721	Margie Tatro, 6100	1	MS 1033	Josh Stein, 6112
1	MS 1324	Rob Leland, 1400	1	MS 0671	Bryan Richardson, 5628
1	MS1104	Juan Torres, 6120	1	MS 0671	Bob Pollock, 5621
1	MS 1104	Rush Robinett, 6110	1	MS 1108	Laurie Burnham, 6111
1	MS 1325	John Mitchiner, 1460	1	MS 0124	Tara Camacho-Lopez, 3601
1	MS 1327	John Wagner, 1462	1	MS 0124	Rene Sells, 1932
1	MS 1108	Ray Finley, 6111	1	MS 0165	Stephanie Holinka, 3601
1	MS 1033	Charlie Hanley, 6112	1	MS 9001	Eric Ridley, 0167
1	MS 1138	Steve Kleban, 6132	1	MS 1082	Tony Lentine, 1727
1	MS 0671	Jennifer Depoy, 5628	1	MS 0968	Michael Bernard, 2611
1	MS 0421	Russ Skocypec, 0240	1	MS 1327	Kiran Lakkaraju, 1462
1	MS 1124	David Minster, 6121	1	MS 1327	Christina Warrender, 1462
1	MS 0351	Hal Morgan, 1930	1	MS 1323	Heidi Thornquist, 1445
1	MS 1318	Tim Trucano, 1441	1	MS 1138	Stephanie Kuzio, 6926
1	MS1033	Abraham Ellis, 6112	1	MS1137	Catherine Jones, 1932
1	MS0372	John Emery, 1524	1	MS1138	Mercy Berman, 1932
1	MS 1137	Thomas Drennen, 6926	1	MS 0734	Lisa Sena-Henderson, 6111
1	MS 9151	Robert Hutchinson, 8960	1	MS1108	Mike Hightower, 6111
1	MS 1140	Ross Guttromson, 6113	1	MS1108	Jason Stamp, 6111
1	MS 1138	Bob Glass, 6132	1	MS 1137	Howard Passell, 6926
1	MS 1138	Theresa Brown, 6924	1	MS 0701	Margaret Walck, 6900
1	MS 1080	Greg Nielson, 1719	1	MS 1004	Melissa Sisneros, 6134
1	MS 0750	Robert Abbot, 6913			

DOE Headquarters

Patricia Hoffman, DOE Assistant Secretary for the Office of Electricity Delivery and Energy Reliability

Dan Ton, DOE Office of Electricity Delivery and Energy Reliability

Gil Bindewald, DOE Office of Electricity Delivery and Energy Reliability

Eric Lightner, DOE Office of Electricity Delivery and Energy Reliability

Sara Kidder, National Energy Technology Laboratory

Deborah Buterbaugh, National Energy Technology Laboratory

Vermont Congressional Delegation

Bernie Sanders, United States Senator, State of Vermont

Huck Gutman, Chief of Staff, Office of U.S. Senator Bernie Sanders

Darren Springer, Senior Policy Advisor, Energy and Environment, Office of U.S. Senator Bernie Sanders

Patrick Leahy, United States Senator, State of Vermont

Christopher Saunders, Office of U.S. Senator Patrick Leahy

Tom Berry, Office of U.S. Senator Patrick Leahy

Peter Welch, United States Representative, State of Vermont

Jon Copans, Office of U.S. Representative Peter Welch
Jeff Bingaman, United States Senator, State of New Mexico
Bob Simon, Staff Director, Senate Energy and Natural Resources Committee, U.S. Senate

State of Vermont

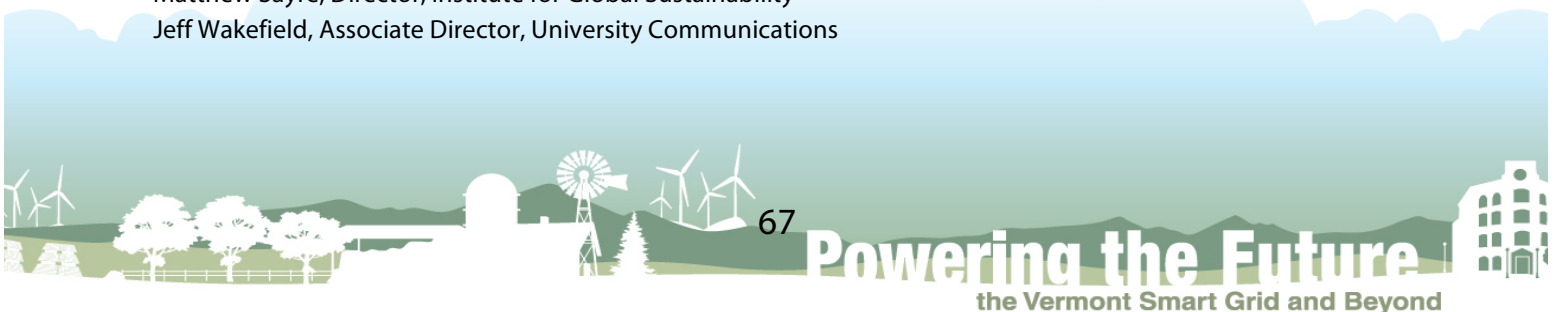
Peter Shumlin, Governor, State of Vermont
Bill Lofy, Chief of Staff, Governor Shumlin
Elizabeth Miller, Commissioner, Vermont Department of Public Service
Asa Hopkins, Director, Energy Policy and Planning, Vermont Department of Public Service
Hans Mertens, Director of Engineering, Vermont Department of Public Service
James Porter, Director of Telecommunications, Vermont Department of Public Service
Evan Shearer, Telecommunications Infrastructure Specialist, Vermont Department of Public Service
Tamera Pariseau, Team Leader for Consumer Affairs and Public Infrastructure, Vermont Department of Public Service
Lawrence Miller, Secretary of Commerce, State of Vermont
Chuck Ross, Secretary of Agriculture, State of Vermont
Karen Marshall, Chief of Connect VT, Agency of Administration, State of Vermont

University of Vermont, Core Team

John Evans, Special Advisor to the University of Vermont President
Domenico Grasso, VP Research & Graduate Studies and Professor of Engineering
Dan Harvey, Chief of Staff, Office of the VP for Research
Jeff Marshall, Professor of Engineering
Melody Burkins, Director of Research & Strategic Initiatives, VP Research Administration Office
Wendy Koenig, Director of Federal Relations

University of Vermont Faculty and Staff

Cynthia Belliveau, Dean of Continuing Education
Kelvin Chu, Associate Director of EPScOR
Peter Dodds, Associate Professor of Mathematics & Statistics
Margaret Eppstein, Associate Professor of Computer Science
Paul Hines, Assistant Professor of Electrical Engineering
Jeff Frolik, Associate Professor of Electrical Engineering
Diann Gaalema, Postdoctoral Research Fellow, Psychiatry
Stephen Higgins, Professor of Psychiatry
Chris Koliba, Associate Professor of Community Development & Applied Economics
Donna Rizzo, Associate Professor of Civil & Environmental Engineering
Judith Van Houten, Director of EPScOR
Asim Zia, Associate Professor of Community Development & Applied Economics
Tracey Maurer, Director, Center for Leadership and Innovation, School of Business Administration
Matthew Sayre, Director, Institute for Global Sustainability
Jeff Wakefield, Associate Director, University Communications



Vermont Utilities

Larry Reilly, President, Central Vermont Public Service Corporation
Jeff Monder, CIO, Central Vermont Public Service Corporation
Mike Tucci, Central Vermont Public Service Corporation
Barbara Grimes, General Manager, Burlington Electric Department
Jim Merriam, Director, Efficiency Vermont
Mary Powell, CEO, Green Mountain Power
Brian Otley, COO, Green Mountain Power
Josh Castonguay, Field Operations Leader, Green Mountain Power
Mary Morris, Project Manager, Green Mountain Power
Ellen Burt, General Manager, Stowe Electric Department
David Hallquist, CEO, Vermont Electric Coop
Randy Pratt, Manager of Policy and Programs, Vermont Electric Coop
Christopher Dutton, President and CEO, Vermont Electric Power Company
Kerrick Johnson, Vice President, External Affairs, Vermont Electric Power Company
Allen Stamp, Program Manager e-Energy Vermont, Vermont Electric Power Company
Scott Johnstone, CEO, Vermont Energy Investment Corporation
Karen Glitman, Director of Transportation Efficiency, Vermont Energy Investment Corporation
Shawn Enterline, Senior Consultant, Vermont Energy Investment Corporation
Ethan Goldman, Measurement & Verification Specialist, Vermont Energy Investment Corporation
David Mullet, General Manager, Vermont Public Power Supply Authority
Avram Patt, General Manager, Washington Electric Cooperative

e-Energy Vermont Communications Working Group

Amanda Beraldi, Strategic Planning Manager, Central Vermont Public Service Corporation
Steve Costello, Director of Public Affairs, Central Vermont Public Service Corporation
Robert Dostis, Leader of Customer Relations and External Affairs, Green Mountain Power
Tom Buckley, Manager, Customer and Energy Services, Burlington Electric
Bill Powell, Washington Electric Coop
George Twigg, Deputy Policy Director, Vermont Energy Investment Corporation
Deena Frankel, Strategic System Planning Facilitator, Vermont Electric Power Company
Liz Gamache, Manager of Corporate Services, Vermont Electric Coop
Joanne Heidkamp, Communications Team, Green Mountain Power
Dorothy Schnure, Manager, Corporate Communications, Green Mountain Power
Mary Sullivan, Communications Coordinator, Burlington Electric Department
Shana Duval, External Affairs Assistant, Vermont Electric Power Company

Other Stakeholders

Michael Dworkin, Director, Institute for Energy and the Environment, Vermont Law School
Kevin Jones, Smart Grid Project Leader, Vermont Law School
Rebecca Wigg, Smart Grid Fellow, Vermont Law School
Stephen Fitzhugh, Associate Professor and Chair, Electrical and Computer Engineering, Norwich University
Phil Susmann, President Applied Research Institutes, Norwich University
Phelan Fretz, Executive Director, ECHO Lake Aquarium and Science Center
Molly Loomis, Director of Education, ECHO Lake Aquarium and Science Center

Linda Bowmen, Lifelong Learning Coordinator and Educator, ECHO Lake Aquarium and Science Center
Tim Donovan, Chancellor, Vermont State Colleges
Dan Smith, Director of Community Relations and Public Policy, Vermont State Colleges
Janette Bombardier, Senior Location Executive, IBM Essex
Kristofor Sellstrom, Junior Electrical Engineer, Jamestown Board of Public Utilities
Brianna Baker, Senior, University of Vermont
Lieutenant Colonel Adam Rice, Vermont Air National Guard

Private Sector

Randy Mead, VP, Building Performance Division, Control Technologies
David Blittersdorf, CEO, AllEarth Renewables
Jan Blittersdorf, CEO, NRG Systems
Bryan Randall, Director of Operations, Draker Laboratories
Peter Pollak, CEO, DynaPower
Adam Knudsen, Chief of Operations, DynaPower
Kyle Clark, Engineering Manager, DynaPower
Jeff Wolfe, CEO, GroSolar
Jon Cohn, IBM Fellow, IBM
Gordon Bristol, Project Manager, Omega Optical
Brad Gordon, Executive Assistant and Government Liaison, SBElectronics

University of Vermont, CETI Core Team

John Evans, Special Advisor to the University of Vermont President
Domenico Grasso, VP Research & Graduate Studies and Professor of Engineering
Dan Harvey, Chief of Staff, Office of the VP for Research
Jeff Marshall, Professor of Engineering
Melody Burkins, Director of Research & Strategic Initiatives, VP Research Administration Office
Wendy Koenig, Director of Federal Relations

University of Vermont Faculty

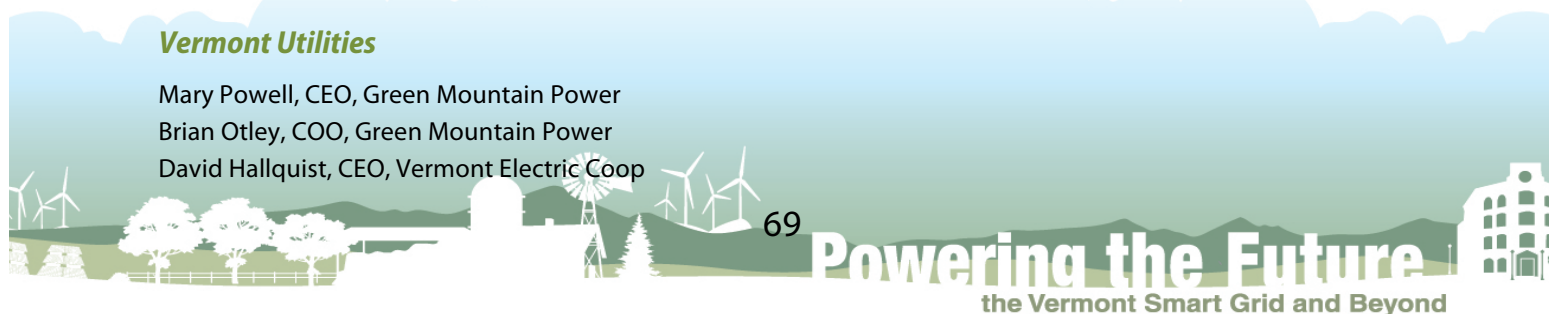
Margaret Eppstein, Associate Professor of Computer Science
Donna Rizzo, Associate Professor of Civil & Environmental Engineering
Chris Koliba, Associate Professor of Community Development & Applied Economics
Paul Hines, Assistant Professor of Electrical Engineering

University of Vermont Faculty (continued)

Asim Zia, Associate Professor of Community Development & Applied Economics
Jeff Frolick, Associate Professor of Electrical Engineering
Diann Gaalema, Postdoctoral Research Fellow, Psychiatry
Tracey Maurer, Director, Center for Leadership and Innovation, School of Business Administration
Jeff Wakefield, Associate Director, University Communications

Vermont Utilities

Mary Powell, CEO, Green Mountain Power
Brian Otley, COO, Green Mountain Power
David Hallquist, CEO, Vermont Electric Coop



Randy Pratt, Manager of Policy and Programs, Vermont Electric Coop
Kerrick Johnson, Vice President, External Affairs, Vermont Electric Power Company
Allen Stamp, Program Manager e-Energy Vermont, Vermont Electric Power Company
Scott Johnstone, CEO, Vermont Energy Investment Corporation
Jeff Monder, CIO, Central Vermont Public Service

e-Energy Vermont Communications Working Group

Amanda Beraldi, Central Vermont Public Service
Robert Dostis, Leader of Customer Relations and External Affairs, Green Mountain Power
Tom Buckley, Manager, Customer and Energy Services, Burlington Electric
Bill Powell, Washington Electric Coop
George Twigg, Deputy Policy Director, Vermont Energy Investment Corporation
Deena Frankel, Strategic System Planning Facilitator, Vermont Electric Power Company
Liz Gamache, Manager of Corporate Services, Vermont Electric Coop
Joanne Heidkamp, Communications Team, Green Mountain Power
Mary Sullivan, Communications Coordinator, Burlington Electric Department
Hans Mertens, Director Engineering Services and Chief Engineer, Vermont Department of Public Service

Other Stakeholders

Michael Dworkin, Director, Institute for Energy and the Environment, Vermont Law School
Kevin Jones, Smart Grid Project Leader, Vermont Law School
Stephen Fitzhugh, Associate Professor and Chair, Electrical and Computer Engineering, Norwich University
Phil Susmann, President Applied Research Institutes, Norwich University
Phelan Fretz, Executive Director, ECHO
Tim Donovan, Chancellor, Vermont State Colleges
Janette Bombardier, Senior Location Executive, IBM Essex
Karen Glitman, Director of Transportation Efficiency, Vermont Energy Investment Corporation

Private Sector

Randy Mead, VP, Building Performance Division, Control Technologies
David Blittersdorf, CEO, AllEarth Renewables
Jan Blittersdorf, CEO, NRG Systems
Bryan Randall, Director of Operations, Draker Laboratories
Peter Pollak, CEO, DynaPower
Jeff Wolfe, CEO, GroSolar
Gordon Bristol, Project Manager, Omega Optical
Brad Gordon, Executive Assistant and Government Liaison, SBElectronics

